FINAL SUBMITTAL

VOLUME I

ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS FT. SILL, OKLAHOMA

Prepared for

TULSA DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

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ac	-	alternating current
ACCU	-	air cooled condensing unit
AEL	-	acceptable exposure limit
AHU	-	air handling unit(s)
amp	-	ampere (amp, amps)
ANSI	-	American National Standards Institute
ASCII	-	American Standard Code for Information Interchange
ASHRAE	-	American Society of Heating, Refrigeration, and Air Conditioning Engineers
AWG	-	American wire gauge
bar	-	bar: 14.5 psi
BAU	-	business as usual
B/C	-	benefit-to-cost ratio
Bhp	-	brake horsepower
Bks	-	barracks
BLAST	-	Building Loads Analysis and System Thermodynamics Program, CERL
Bldg	-	building
BOQ	-	Bachelor Officer's Quarters
Btu	-	British thermal units
Btuh	-	British thermal units per hour
B/W	-	black and white
°C	-	Celsius (Centigrade)(degrees)
cc	-	cubic centimeter

ccf	-	one hundred (100) cubic feet
CEP	-	central energy plant
CFC	-	chlorofluorocarbons
cfh	-	cubic feet per hour
cfm	-	cubic feet per minute
ckVAR	-	capacitive kilovolt-ampere reactive
CNW	-	condensed water
CNWP	-	condensed water pump
CNWR	-	condensed water return
CNWS	-	condensed water supply
CO	-	carbon monoxide
COND.	-	condenser
const	-	construction
COP	-	coefficient of performance: ratio of the tons of refrigeration produced to the energy required to operate the equipment
CO_2	-	carbon dioxide
CPU	-	central processing unit
CY	-	current transducer
CTD	-	Carnahan-Thompson-Delano
CTM	-	cooling tower motor
cu ft	-	cubic foot, cubic feet
CW	-	chilled water

CWE	-	current working estimate
CWP	-	chilled water pump
CWR	-	chilled water return
CWS	-	chilled water supply
CV	-	converter
d	-	day(s)
DB	-	dry bulb
DD	-	Degree Day: the difference between the median temperature for any hour and a selected base temperature (generally 65°F)
deg	-	degrees
DEH	-	Director of Engineering and Housing
DHW	-	domestic hot water
Di	-	inside diameter
DOM.	-	domestic
DP	-	differential pressure transducer
DX	-	direct expansion
E_b	-	boiler efficiency
E/C	-	energy-to-cost ratio
ECIP	-	Energy Conservation Investment Program
ECO	-	energy conservation opportunity(s)
EEAP	-	Energy Engineering Analysis Program
eff	-	efficiency

EIC	-	Engineer In Charge
elec	-	electrical
E_m	-	motor efficiency
EMC	-	E M C Engineers, Inc.
EMCS	-	Energy Monitoring and Control System
EPA	-	Environmental Protection Agency
eqpt	-	equipment
F	-	flow meter
°F	-	Fahrenheit (degrees)
FLA	-	full load amps
ft	-	foot, feet
ft^2	-	square feet
ft^3	-	cubic feet
FO	-	fuel oil
gal	-	gallon(s)
g/dscm	-	grams per dry standard cubic meter
gpm	-	gallons per minute
HCFC	-	hydrochlorofluorocarbon
HCP	-	hot/chilled water pump
HCR	-	hot/chilled water return
HCS	-	hot/chilled water supply
HCW	-	hot/chilled water

HG	-	mercury
hp	-	horsepower
hr	-	hour(s)
HTHW	-	high temperature hot water
H&V	-	heating and ventilating
HVAC	-	heating, ventilating, and air conditioning
HW	-	hot water
HWR	-	hot water return
HWS	-	hot water supply
Hz	-	hertz, frequency
in	-	inch(es)
I/O	-	input/output
°K	-	kelvin (degrees)
kip	-	one thousand pounds
kW	-	kilowatt, one thousand watts
kWh	-	kilowatt-hour, one thousand watthours
kV	-	kilovolt, one thousand volts
kVAh	-	kilovolt-ampere hour, one thousand volt-ampere hour(s)
kVAR	-	kilovolt-ampere reactive
kVARh	-	kilovolt-ampere reactive hour, one thousand volt-ampere reactive hour(s)
L	-	length

lb	-	pound(s)
LCC	-	life cycle cost
LCCID	-	life cycle cost in design
LTHW	-	low temperature hot water
m	-	meter
m^3	-	cubic meters
maint	-	maintenance
Mbh	-	Btu per hour (thousand)
mcf	-	one thousand cubic feet
MCP	-	Military Construction Program
Mh	-	man-hour(s)
mm	-	millimeter
MMBtu	-	British thermal units (million)
MMBtuh	-	Btus per hour (million)
mo.	-	month(s)
MUX	-	multiplexer
mW	-	megawatt, one million watts
mWh	-	megawatt-hour, one million watt-hours
MZU	-	multizone unit
N/A	-	not available or not applicable
nat	-	natural (gas)
NBS	-	National Bureau of Standards

NOAA	-	National Oceanic and Atmospheric Administration
no.	-	number
O_2	-	oxygen
OA	-	outside air
O & M	-	operation and maintenance
PD	-	pressure drop or difference
PLT	-	plant
PF	-	power factor: relationship between kW and kVA. When the power factor is unity, kVA equals kW.
PM	-	Project Manager
ppm	-	parts per million
psi(a)(g)	-	pounds per square inch (absolute)(gauge)
Q	-	flow rate
R	-	return
RDF	-	refuse derived fuel
RET.	-	return
RVAC	-	refrigeration, ventilation, air conditioning
R-value	-	the resistance to heat flow expressed in units of (ft^2) x (hours) x (°F)/Btu; R-value = 1/U-value
S	-	supply
scf	-	standard cubic feet
scfm	-	standard cubit feet per minute

SIR	-	Savings-to-Investment Ratio: total life cycle benefits divided by 90% of the differential investment cost
SIOH or SIA	-	supervision, inspection, and overhead
SOW	-	scope of work
sq ft	-	square foot (feet)
st/sp	-	start/stop
SWPA	-	Southwestern Power Administration
SZU	-	single zone unit
stby	-	standby
t	-	ton, a means of expressing cooling capacity: 1 ton - 12,000 Btu/hr cooling
T	-	temperature
temp	-	temperature
TD	-	temperature difference
T_f	-	fluid temperature (°C)
T_g	-	ground temperature (°C)
TPF	-	third party financing
TRY	-	Test Reference Year
UA	-	overall heat transfer coefficient (Btu/hr-°F)
UPW	-	uniform present worth factor: a factor which, when applied to annual savings, will account for the time value of money and inflation over the life of the project
U.S.	-	United States

U-value	-	a coefficient expressing the thermal conductance of a composite structure in Btu per (sq ft)(hour)(°F temperature difference); Btu/ft^2 x hr x °F); U-value = 1/R-value
V	-	volt(s)
VAT	-	value added tax
VAV	-	variable air volume
VSD	-	variable speed drive
W	-	watt(s)
WB	-	wet-bulb
wk	-	week(s)
yr	-	year(s)

SECTION 1.0

INTRODUCTION

1.1 AUTHORITY FOR STUDY

This study was conducted and this submittal prepared under Contract No. DACA56-90-C-0087. The contract was issued by the Corps of Engineers, Tulsa District, on 21 August 1990.

1.2 PURPOSE OF STUDY

This submittal presents the results of a study analyzing energy requirements and energy conservation opportunities (ECOs) for Army boiler and chiller plants at Fort Sill, Oklahoma.

1.3 SCOPE OF WORK

The scope of work (SOW) for this study is defined in the contract SOW entitled "Energy Survey of Army Boiler and Chiller Plants for Fort Sill, Oklahoma," dated 6 June 1990. This study includes the following major tasks:

- Determine the efficiency of boiler and chiller plants by appropriate tests.
- Document the condition, current operating methods, and type of control systems of the boiler and chiller plants.
- Identify ECOs, including low cost or no cost ECOs.
- Calculate the energy and dollar savings and prepare cost estimates for each ECO determined to be technically feasible.
- Calculate the simple payback and savings-to-investment ratio (SIR) for each ECO.
- Illustrate the methods and justifications of the approaches taken.
- Present recommended boiler and chiller operation and maintenance practices, with the intent to increase efficiency.
- Combine technically and economically feasible ECOs into larger packages (in coordination with installation personnel) which will qualify for Energy Conservation Investment Program (ECIP) or Military Construction Program (MCP) funding.

The complete Scope of Work (SOW) for this study and related Confirmation Notices are included as Appendix A of this Volume I, and also as Appendix A of Volume II. For the convenience of reviewers, Table 1-1, starting on page 1-3, presents a detailed list of all items

required by the SOW and indicates where those items are presented in this report. Table 1-2 on page 1-6 presents a list of individual ECOs evaluated. Table 1-3 on page 1-7 presents a list of ECIP projects evaluated in this report.

1.4 ORGANIZATION OF REPORT

Sections 1.1 and 1.2 contain introductory information relevant to the study and the preparation of the report, based on the SOW outlined in Section 1.3. This Section 1.4 explains the organization of the report.

Section 2.0 contains general central plant descriptions, detailed central plant information, operations procedures, and results of testing.

Section 3.0 explains the analysis methodology used in the study, along with Fort Sill utility rates and energy use for FY90.

Section 4.0 evaluates the base energy usage of chillers and boilers, then uses this data, along with the results of the survey, to determine the technical and economic feasibility of potential ECOs.

Section 5.0 presents special considerations and previous study plant evaluations.

Section 6.0 describes low cost or no cost ECOs and operational action items which will affect energy conservation.

Section 7.0 summarizes the identified ECO projects which meet technical and economic criteria.

Section 8.0 presents a summary of findings and recommendations.

TABLE 1-1
SCOPE OF WORK SUMMARY
ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS, Fort SILL, OKLAHOMA

ITEM NO.	SOW PAGE	SOW SECTION	DESCRIPTION	REPORT SECTION
1	1	1.1	Survey the boilers to determine their efficiency.	2.0
2	1	1.3	Identify and list all ECOs considered.	4.0
3	1	1.3	Identify low cost or no cost ECOs.	6.0
4	1	1.6	Prepare report.	-
5	1	2.1	Include in the study the results of previous studies concerning boiler and chiller plants.	5.0
6	2	2.5	Determine if ECOs are technically and economically feasible.	4.0
7	2	2.5	Combine ECOs into larger packages for ECIP or MCP funding.	8.0
8	2	2.6	List and prioritize, by SIR, projects which qualify for ECIP funding.	Table 7-2
9	2	2.7	Prioritize, by SIR, feasible non-ECIP projects.	8.0
10	4	5.1	Develop life cycle cost analysis summary sheets for ECIP projects.	Appendix D
11	4	5.1	Provide original backup calculations from previous studies.	Appendix G and H
12	5	5.2	Develop life cycle cost analysis summary sheets for non-ECIP projects.	Appendix D
13	6	5.3	Document nonfeasible ECOs in the report.	4.0
14	6	7.1.1	Conduct boiler efficiency tests.	Appendix F, Survey Notes
15	6	7.1.2	Conduct chiller efficiency tests.	Appendix E, Survey Notes

TABLE 1-1
SCOPE OF WORK SUMMARY (Continued)
ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS, Fort SILL, OKLAHOMA

ITEM NO.	SOW PAGE	SOW SECTION	DESCRIPTION	REPORT SECTION
16	7	7.2.2	Investigate existing local controls and incorporate into EMCS.	4.0
17	7	7.2.3	Review, document, and evaluate operation and maintenance practices.	2.0 and 6.0
18	7	7.3	Thoroughly evaluate and document all potential ECOs which are not eliminated.	Appendix D
19	8	7.6	Prepare a comprehensive report.	Interim Submittal
20	10	7.6.1	Interim submittal - include analyses performed to date and results of field survey.	Interim Submittal
21	10	7.6.1	Interim submittal - include copies of the Scope of Work and any modifications.	Appendix A
22	10	7.6.1	Interim submittal - provide a narrative summary.	Executive Summary
23	10	7.6.1	Interim submittal - include copies of field survey forms.	Appendix E and F
24	10	7.6.2	Prefinal submittal - document the integrated aspects of the study.	8.0
25	10	7.6.2	Prefinal submittal - include an order of priority, by SIR, for the recommended ECOs.	8.0
26	11	7.6.2	Prefinal submittal - include an executive summary per Annex D.	Executive Summary
27	11	7.6.2	Prefinal submittal - list all projects and ECOs developed in the study.	7.0 and 8.0

TABLE 1-1
SCOPE OF WORK SUMMARY (Concluded)
ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS, Fort SILL, OKLAHOMA

ITEM NO.	SOW PAGE	SOW SECTION	DESCRIPTION	REPORT SECTION
28	11	7.6.3	Final Report - incorporate revisions and corrections resulting from comments.	Final Report
29	11	8.0	Identify operational items noted in the study which will effect energy conservation.	Section 6.0
30	6	7.1.1 & 7.1.2	Use metering equipment with the proper accuracies and calibration.	Appendix E
31	A-17	-	Present overview of the impact on changing refrigerants to environmentally safe refrigerants.	Section 5.0
32	-	-	Plants included in study: 730, 914, 2812, 4701, 5676, 5678, 5900, 6003.	-

TABLE 1-2
SCOPE OF WORK SUMMARY, ECOs EVALUATED
ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS, Fort SILL, OKLAHOMA

ECO DESCRIPTION IN SOW	SOW LOCATION	ECO NO.	ECO DESCRIPTION IN REPORT
Controls to assure proper combustion air-fuel ratio.	Annex A	10	Installation of combustion controls.
Installation of new burner equipment.	Annex A	11	Installation of new high efficiency burner.
Economizer or air preheater.	Annex A	12	Installation of stack economizer or air preheater.
Loading characteristics and scheduling versus equipment capacity (equipment optimization).	Annex A	2 & 8	2 - Chiller optimization. 8 - Boiler optimization.
Control systems to operate chillers at the most energy efficient operating condition.	Annex A	2	Chiller optimization.
Variable or two-speed cooling tower fan.	Annex A	5(A) & 5(B)	5(A) Two-speed motors. 5(B) Variable speed control.
Storage of chilled water or other thermal storage systems.	Annex A & Conf. Notice 1	4	Ice storage cooling system.
High efficiency motors.	Annex A	6	High efficiency motors.
Instruments and controls to facilitate efficient operations.	Annex A	1 & 7	1 - Chiller instruments. 7 - Boiler instruments.
Use smaller boilers where load has been reduced.	Annex A	8	Boiler optimization.
Replace inefficient boilers with more efficient boilers (or repair).	Annex A (para 7.2.1)	9	Renovate or replace boilers.
Replace inefficient chillers with more efficient chillers (or repair).	Annex A (para 7.2.1)	3	Renovate or replace chillers.

TABLE 1-3
PROJECTS EVALUATED - PREFINAL SUBMITTAL
ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS, Fort SILL, OKLAHOMA

PROJECT NUMBER	PROJECT DESCRIPTION
1	Control project for Central Plants 730, 5900, and 6003.
2	Central heating plant project and control project for Buildings 5676 and 5678.
3	Replace boilers 1 and 2 in Central Plants 2812 and 5900.
4	Replace a chiller in Central Plant 2812 with a higher efficiency chiller.
5	Compare local hot water boiler in each barracks versus central heating plant project.

SECTION 2.0

FACILITY INFORMATION

2.1 GENERAL

Established in 1869, Fort Sill was originally a cavalry post established to control hostile Southern Plains Indian tribes. Through two world wars and two regional wars, Fort Sill has continued to grow and play a vital role in the nation's defense. Today, as the home of the U.S. Army Field Artillery School and the U.S. Army Field Artillery Training Center, the post has a population of 18,693 military personnel. Fort Sill is the artillery headquarters of the Free World nations, training servicemen from the United States and the allied nations on its 94,268 acres.

Over the past decade, the fort has received a major facelift; more than $150 million has been invested in new construction, including new trainee barracks, a physical fitness center, and a new hospital.

2.2 CENTRAL PLANT DESCRIPTIONS, OPERATION, AND TESTING

The following sections provide a description of each of the central plants as they exist today. During the field survey, the condition and operation of the central plants were noted. These notes are also summarized in the following section.

To evaluate the energy requirements and ECOs for Army boiler and chiller plants at Fort Sill, it was necessary to inspect and test the nine central plants. Chiller testing, which was performed in September 1990, included obtaining a single set of readings on the following points:

- Condenser water inlet temperature
- Condenser water outlet temperature
- Chilled water return temperature
- Chilled water supply temperature
- Chilled water flow
- Chiller compressor kW input
- Outside air temperature
- Outside air relative humidity
- Chilled and condenser water pumps kW input
- Chilled and condenser water pumps differential pressure
- Condenser inlet and outlet pressure differential
- Evaporator inlet and outlet pressure differential.

Figure 2-1 on page 2-4 schematically depicts the chiller testing points. The test procedures were as follows:

- Installed all chiller test equipment.
- Manually unloaded chiller to falsely increase cooling load.
- Adjusted setpoints to normal positions, and took multiple readings after steady-state conditions were established.
- Removed instrumentation.
- Interviewed DEH personnel as to operation and maintenance (O & M) procedures.

Boiler testing, performed in February 1990, included readings of the following points:

- Flue gas temperature
- Ambient (combustion) air temperature
- Flue gas CO content
- Flue gas O_2 content
- Outside air temperature
- Outside air relative humidity
- Fuel flow (using existing meters, where available)
- The kW input to representative large primary hot water circulation pumps
- Differential pressure on representative large primary hot water circulation pumps.

Figure 2-2 on page 2-5 schematically depicts the boiler testing points. The test procedures were as follows:

- Installed flue gas thermometer and sampling tube in stack.
- Set burner controls for non-modulating burners to low and high fire settings.
- Set burner control for modulating burners to low, 50%, 75%, and 100% fire settings.
- Recorded readings at different burner settings.
- Removed instrumentation; returned control settings to original positions.
- Observed the following conditions during the test:
    - Steam or hot water, pressure and temperature setpoints.
    - Boiler water level.
    - Flame configuration.

- Combustion controls.

- Make-up water controls.

- General condition of boiler, including insulation, leaks, boiler water level, flame configuration, combustion controls, and make-up water controls.

The measurement instruments used to test chillers and boilers were calibrated prior to the field survey. The accuracies of the measurement instruments are listed below:

- Flow meter, ± 5%

- Water temperature digital thermometer, ± 0.1%

- Electric meter:

  - Volt, ± 1%
  - Amperes, ± 1%
  - kW/kVAR, ± 2% for 1ϕ and ± 3% for 3ϕ

- Temperature and humidity digital meter:

  - Temperature, ± 0.9%
  - Humidity, ± 0.4%

- Combustion gas monitor:

  - Oxygen, ± 0.4%
  - Carbon Monoxide, ± 5%
  - Temperature, ± 3%

- Pressure test gauges, ± 0.25%

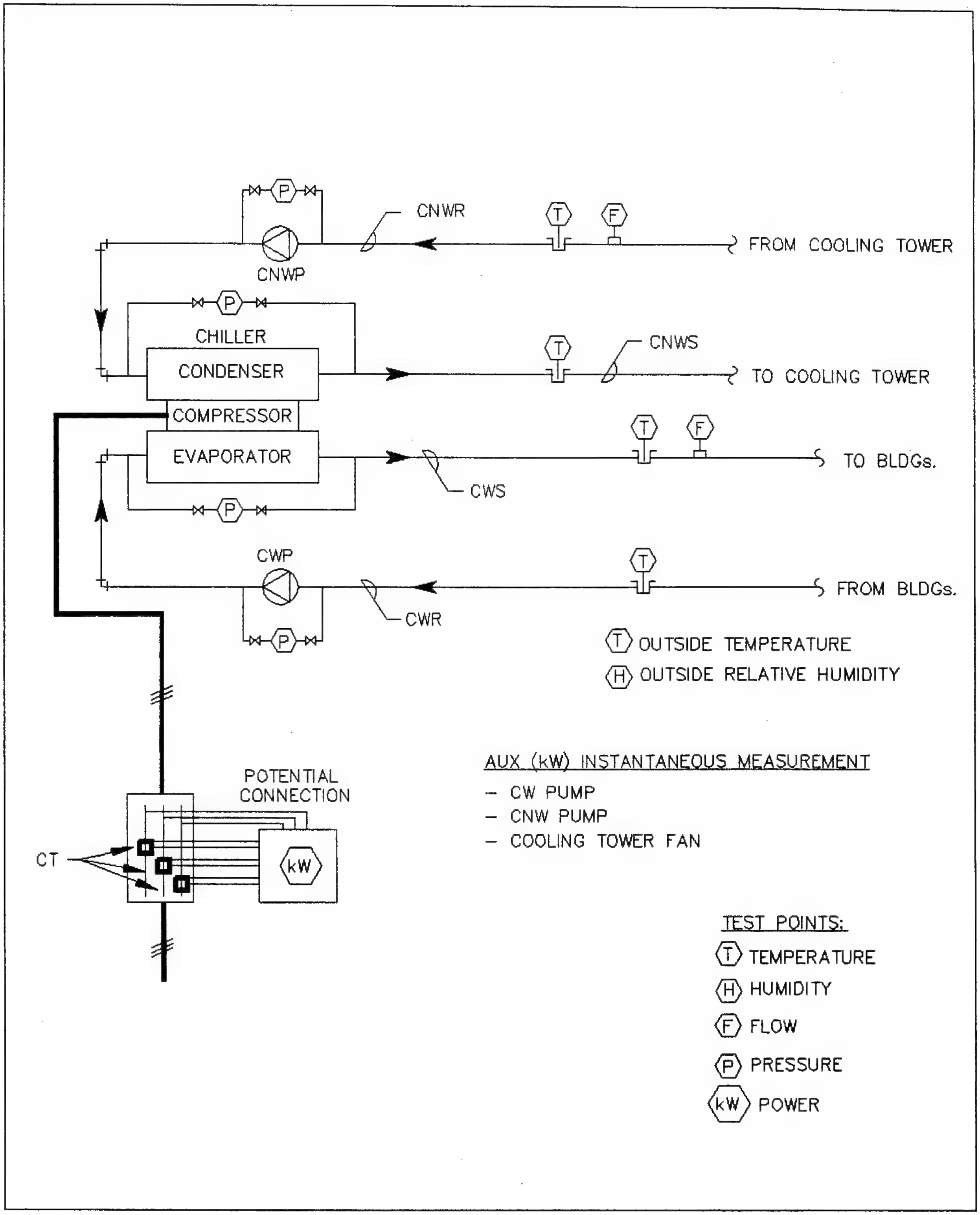


FIGURE 2-1. CHILLER TESTING

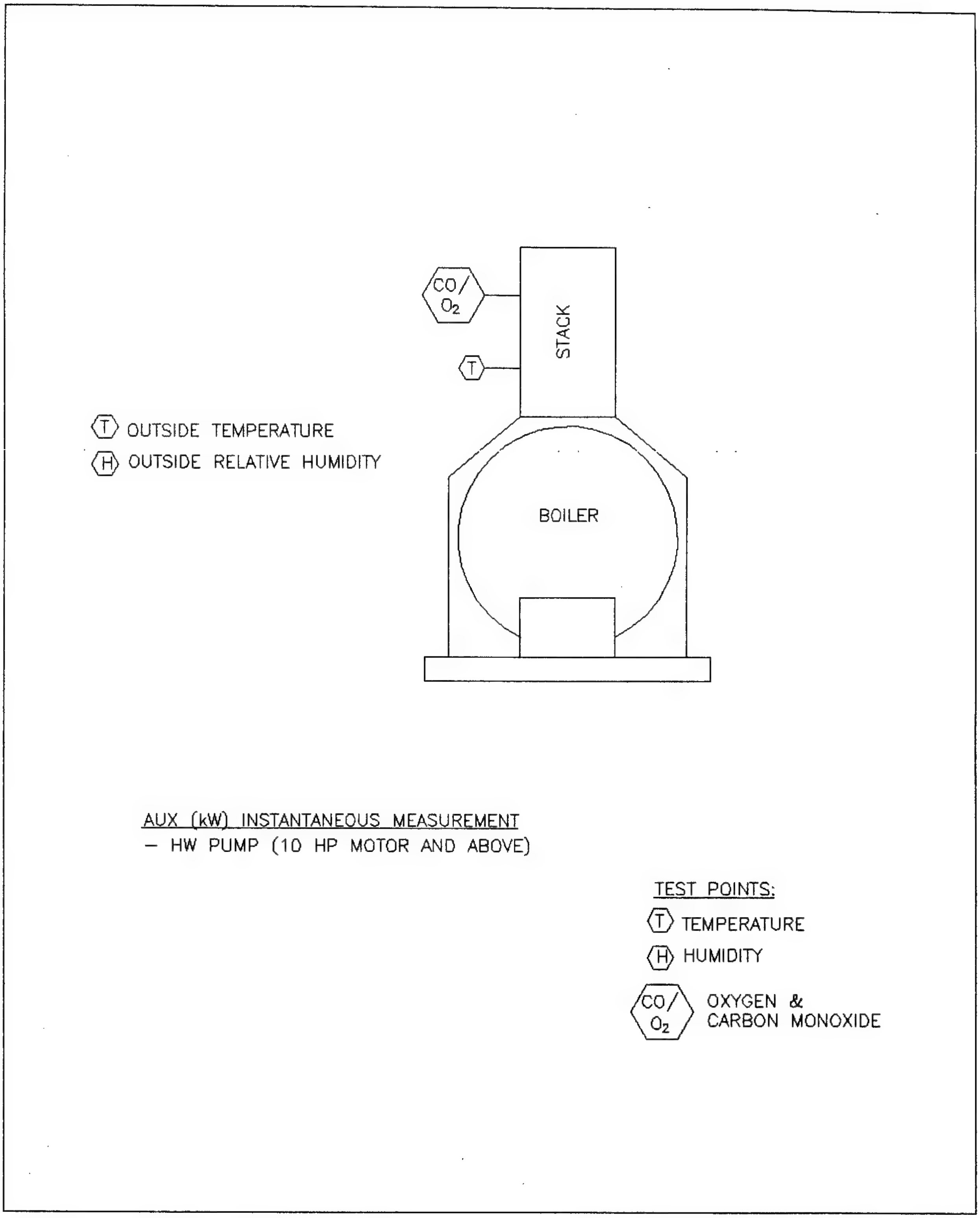


FIGURE 2-2. BOILER TESTING

2.2.1 Central Plant 730

Central Plant 730 was constructed in 1952. This central plant has three centrifugal chillers and four low pressure steam boilers. Two 320 ton chillers (chillers 3 and 4) were replaced in 1980. The 800 ton chiller (chiller 1) and two 150 hp chilled water pumps were replaced in 1982. Four boilers were replaced in 1986 and one cooling tower was replaced in 1974. The central plant serves a total of four buildings and has a nominal design capacity of 1,440 tons cooling and 25.91 MMBtu heating. See Appendix E for a detailed listing of all chiller-related equipment and Appendix F for a detailed listing of all boiler-related equipment. Table 2-1 on page 2-42 lists buildings connected to the central plant. Table 2-2 on page 2-45 lists the major equipment for Central Plant 730. Figures 2-3 and 2-4 on pages 2-9 and 2-10 schematically depict the piping of the chillers and boilers.

2.2.1.1 Central Plant 730 Chiller Operational Observations and Testing

Chiller 1 is run from about May 1 through October 1; the start date depends upon the arrival of continuous hot weather. Two chilled water pumps and one condenser water pump, either condenser pump 1 or pump 2, are operated all summer. During the hottest part of summer, the small condenser water pump, pump 3, is added. During the summer months, chiller 1 is run continuously. In early spring and late fall, chiller 1 is not used at night.

During the summer, one of the chilled water pumps in Building 730, located in the central plant room, operates to serve the AHUs in Building 730.

There is no chiller 2.

In early spring and late fall, chiller 3 operates to serve Building 730. One of the chilled water pumps and condenser water pump 3 also operate; the main chilled water pumps do not run.

Chiller 4 was not operational during the survey because of seal problems causing refrigerant leaks.

The chillers provide a chilled water supply at a temperature of 42°F. Two single-speed fans on the cooling tower cycle to maintain an 80°F condenser water supply temperature to the chillers.

No logs for the chiller plant are kept. Except for thermometers on each chiller and pressure gauges on the pumps and chillers, no plant instrumentation exists.

Comments on the plant:

- Chiller 1 had no special problems noted.
- Chiller 3 had no special problems noted.

- Chiller 4 has seal problems resulting in refrigerant leaks, and is currently not operational.

- The main chilled water pumps, 1 and 2, were recently overhauled. Insulation on the pumps has been removed, and the pump bases need to be grouted.

- Condenser water pumps, 1, 2, and 3 had no special problems noted. The pump bases need to be grouted.

- The water level in the cooling tower was below the two-cell partition, causing a short circuit of airflow from cell to cell.

Recommended operating instructions are provided in Section 6.0, including detailed instructions on how the chillers, setpoints, and pumps should operate under given circumstances. Appendix C.1 provides the results of the chiller testing for Central Plant 730. The chiller efficiency test results for the three chillers were:

- Chiller 1: 0.89 kW per ton
- Chiller 2: (no chiller 2)
- Chiller 3: 0.74 kW per ton
- Chiller 4: (not operational).

2.2.1.2 Central Plant 730 Boiler Operational Observations and Testing

The four boilers in the mechanical room of Central Plant 730 are low pressure steam boilers. These boilers serve Buildings 700, 707, 730, and 840. Boilers 1, 2, and 3 each have a capacity of 7.750 MMBtu. The fourth boiler has a capacity of 2.658 MMBtu. All four boilers are individually controlled at a supply steam pressure setting of 11 psig.

Boilers 1, 2, and 3 operate during the winter for heating; only boiler 4 operates during the summer, for domestic hot water (DHW). The operators reported no major problems with boilers 2, 3, and 4. However, boiler 1 was reported to have a problem with soot, indicating incomplete combustion. According to its operator, the boiler has had problems in the past. Boiler 1 could not be tested during the survey because of boiler problems. The other three boilers operated properly during testing. These boilers are monitored by the boiler operator daily; no log of the boilers is kept.

Three steam converters generate hot water for the buildings listed above. Hot water is circulated to the buildings by two circulation pumps which, connected in parallel, continuously operate year-round.

The boiler efficiency test results for the three boilers were:

- Boiler 2 81.4% efficiency
- Boiler 3 81.7% efficiency

- Boiler 4 81.5% efficiency.

Appendix C.2 provides the results of the boiler testing for Central Plant 730.

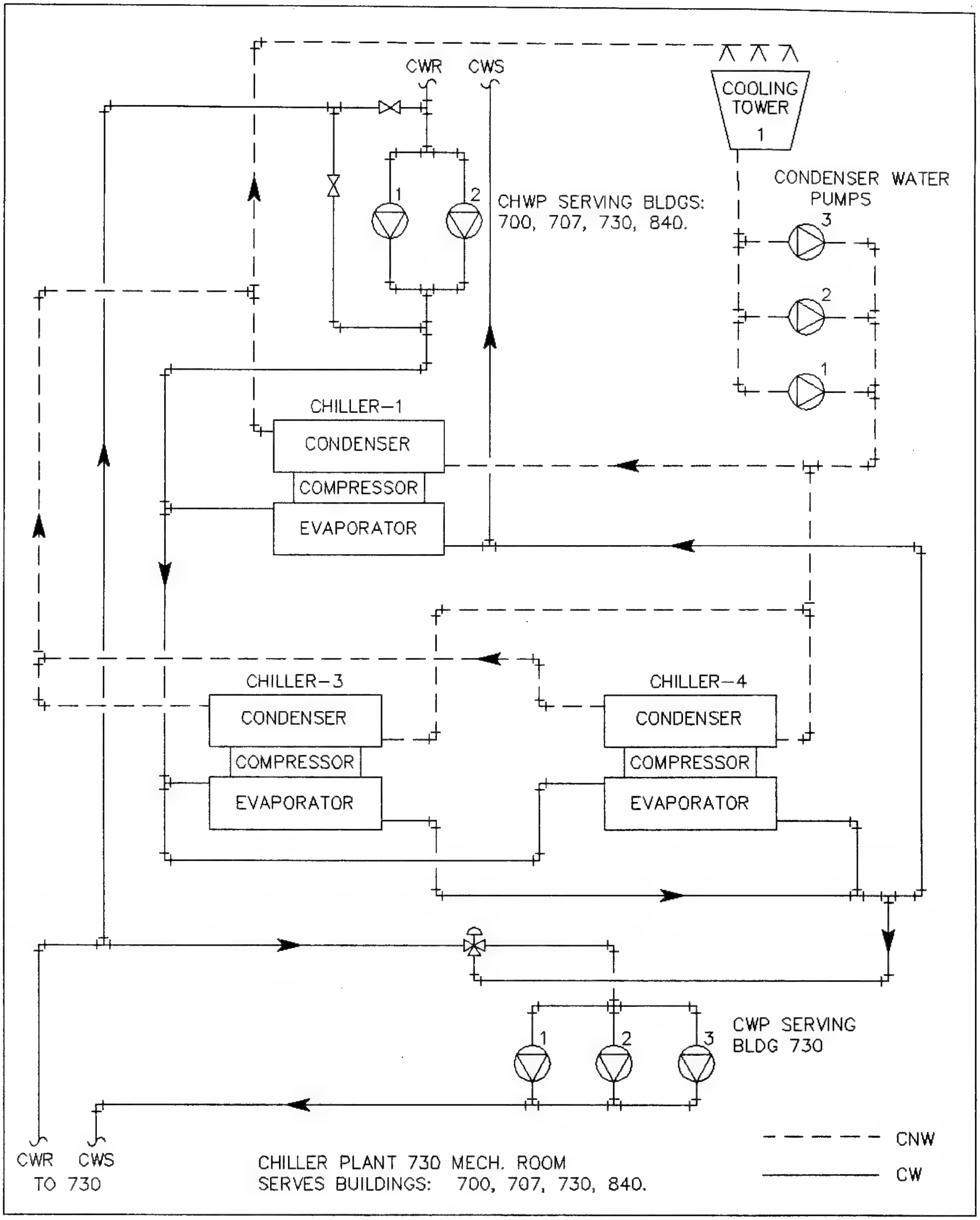


FIGURE 2-3. SCHEMATIC OF CHILLERS, CENTRAL PLANT 730

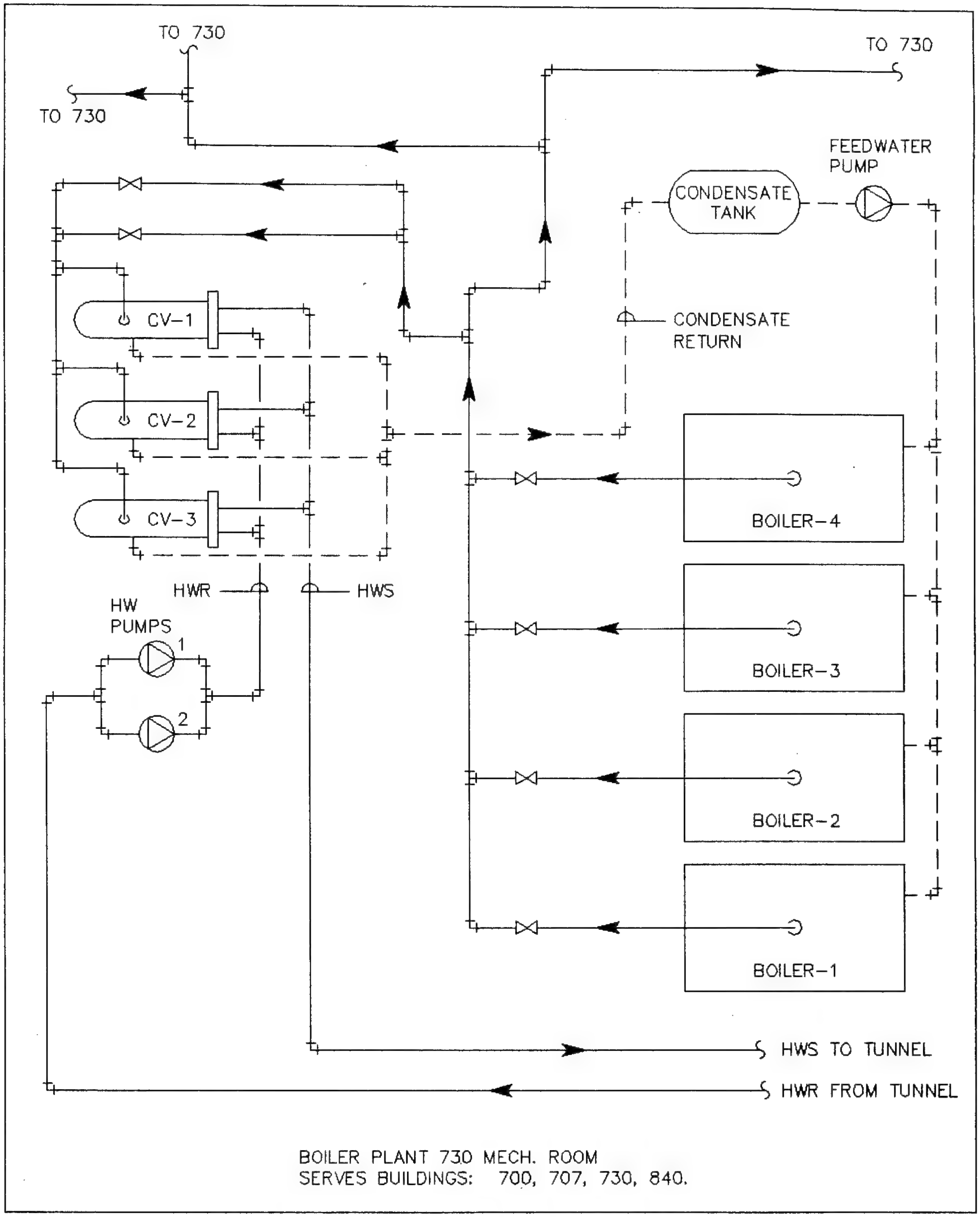


FIGURE 2-4. SCHEMATIC OF BOILERS, CENTRAL PLANT 730

2.2.2 Central Plant 914

Central Plant 914 has one chiller and four boilers, three low temperature hot water (LTHW) boilers, and one low pressure steam boiler. The chiller in Central Plant 914 was replaced in 1989. The chiller plant serves a total of four buildings and has a nominal design capacity of 400 tons cooling; the boiler plant serves only Building 914 and has a nominal design capacity of 7.06 MMBtu heating. See Appendix E for a detailed listing of all chiller-related equipment and Appendix F for a detailed listing of all boiler-related equipment. Table 2-1 on page 2-42 lists buildings connected to the central plant. Table 2-2 on page 2-45 lists the major equipment for Central Plant 914. Figures 2-5 and 2-6 on pages 2-13 and 2-14 schematically depict the piping of the boilers and chiller.

2.2.2.1 Central Plant 914 Chiller Operational Observations and Testing

This chiller, including the chilled water pump, condenser water pump, and cooling tower, is run continuously during the summer. At a chilled water supply setpoint of 43°F, 4° TD, and the current limit controller set at 100%, the chiller surged. The measured pressure drop across the evaporator was much higher than the original design maximum pressure drop, which may indicate clogged or badly fouled tubes. The chiller has electronic microprocessor-based controls. In addition, a CSI Corporation EMCS panel controls the plant and cooling tower, with communication capability through dial-up modems to the DEH RVAC Shop Office in Central Plant 1950. The CSI panel was not operational at the time of the survey.

A heat recovery condenser used to heat domestic water was operating at the time of the survey.

The two-cell cooling tower is equipped with fans 1 and 2, two-speed units which cycle to maintain condenser water temperature setpoint. The tower control is set to bring on cooling tower cells in the following order: cell 1, low at 85°F; cell 2, low at 87°F; cell 1, high at 89°F; and cell 2, high at 91°F. At the time of the survey, only one fan was running.

Comments on the plant:

- The chiller, less than one year old, seemed physically in good condition; however, it surged and was able to operate at only a fraction of its rated capacity.
- Chilled water pump had no special problems noted. The pump base was grouted.
- Condenser water pump had no special problems noted. The pump base was grouted.
- The water treatment system was not operational.
- The water level in the cooling tower was below the two-cell partition, causing a short circuit of airflow from cell to cell.

Recommended operating instructions are provided in Section 6.0, including detailed instructions on how the chiller, setpoints, and pumps should operate under given circumstances. Appendix C.1 provides the results of the chiller testing for Central Plant 914. The efficiency test results for the chiller were:

- Chiller 1: 1.23 kW per ton.

2.2.2.2 Central Plant 914 Boiler Operational Observations and Testing

Central Plant 914 has four boilers used for heating and DHW. The rated output capacity of boilers 1 and 2 is 1.61 MMBtu each, and the capacity of boilers 3 and 4 is 1.92 MMBtu each. Boiler 1 is a low pressure steam boiler used only for DHW. The other boilers are hot water boilers which supply hot water for heating.

Boiler 1 is controlled by a pressure control setting of 12 psig. The other three boilers are controlled by a hot water (HW) supply temperature setting of 140°F. Operators have had to remove soot from boilers 3 and 4 during the past two summers. The soot was apparently caused by the poor arrangement of individual outlets into the common breaching, and perhaps because the nearest boiler to the stack is a forced-draft burner, which may create a positive draft from the other three atmospheric boiler burners.

To provide heating, boiler 2 typically operates on mild winter days, while boilers 3 and 4 operate on cold winter days. Boiler 1 operates year-round, generating steam which is used to generate DHW. Winter months of operation are from around October to April.

Two hot water pumps, configured in parallel, circulate heating water throughout the building. These pumps run continuously during the heating season. Boilers are monitored weekly by the operators; no log of the boilers is kept. The boiler efficiency test results for the four boilers were:

- Boiler 1 82.0% efficiency
- Boiler 2 77.4% efficiency
- Boiler 3 77.9% efficiency
- Boiler 4 74.4% efficiency.

Appendix C.2 provides the results of the boiler testing for Central Plant 914.

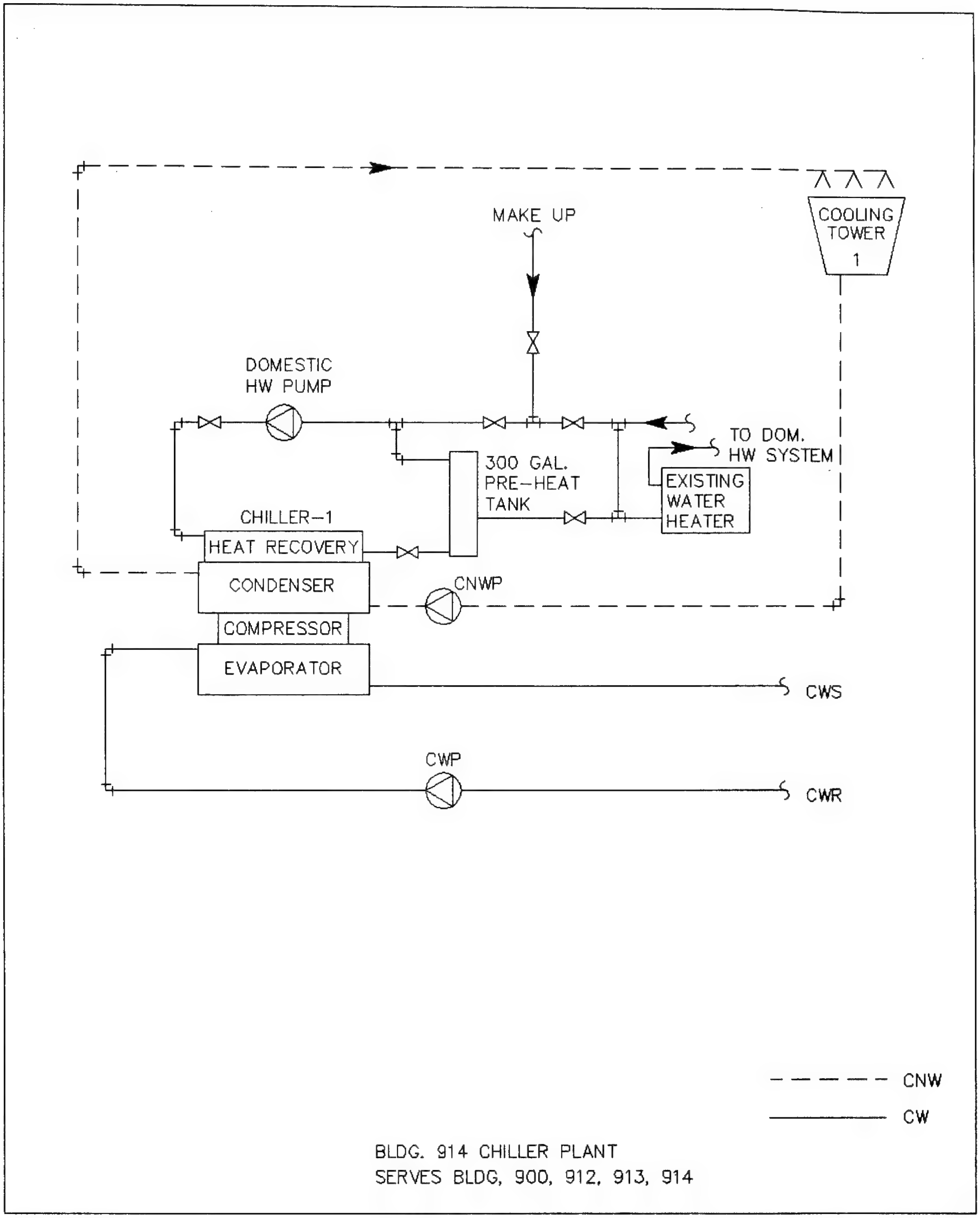


FIGURE 2-5. SCHEMATIC OF CHILLERS, CENTRAL PLANT 914

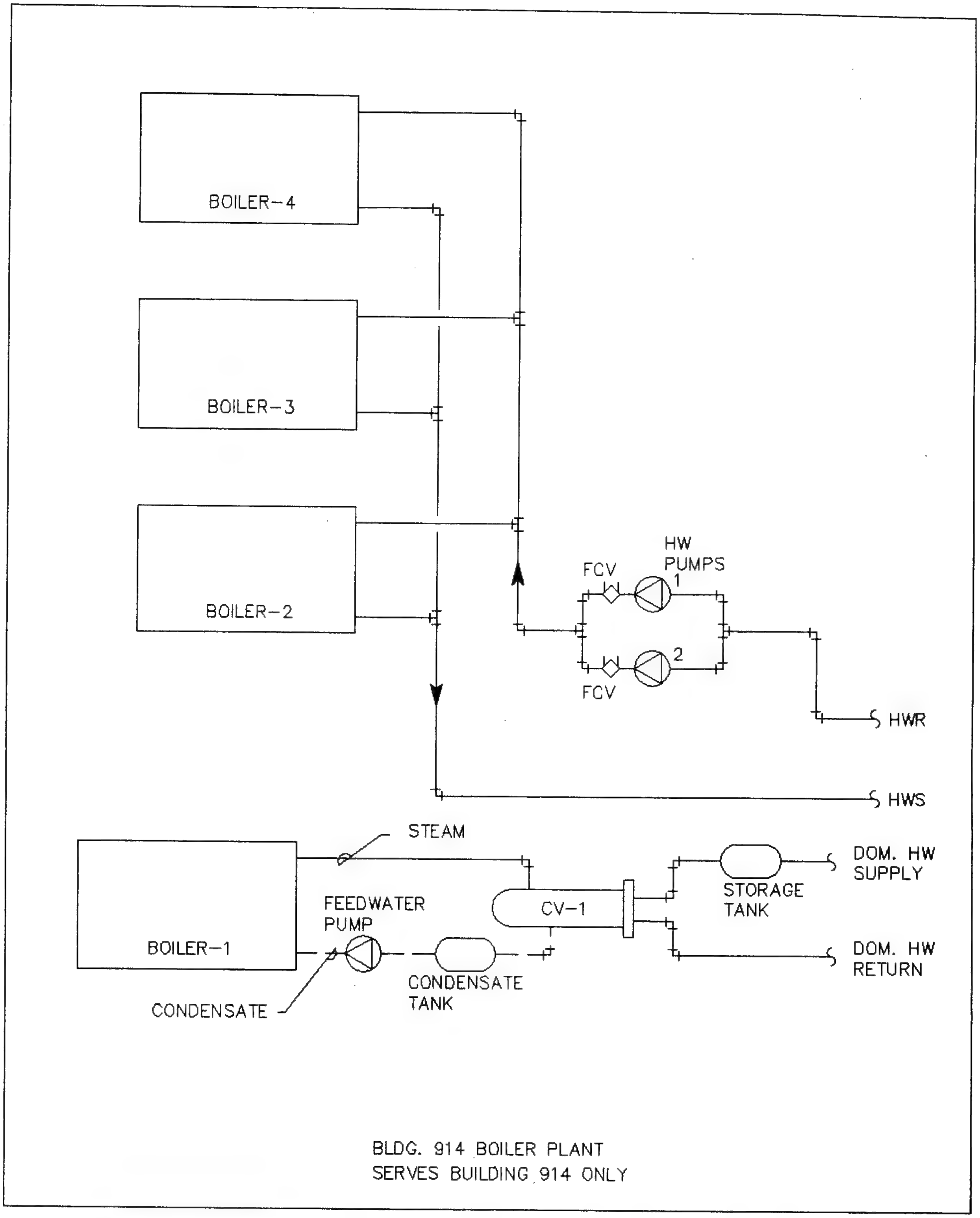


FIGURE 2-6. SCHEMATIC OF BOILERS, CENTRAL PLANT 914

2.2.3 Central Plant 2812

Central Plant 2812 was constructed in 1975. The central plant has one centrifugal chiller, two LTHW boilers, and one low pressure steam boiler. The central plant serves a total of 15 buildings and has a nominal design capacity of 372 tons cooling and 9.7 MMBtu heating. See Appendix E for a detailed listing of all chiller-related equipment and Appendix F for a detailed listing of all boiler-related equipment. Table 2-1 on page 2-42 lists buildings connected to the central plant. Table 2-2 on page 2-45 lists the major equipment for Central Plant 2812. Figures 2-7 and 2-8 on pages 2-17 and 2-18 schematically depict the piping of the boilers and chiller.

2.2.3.1 Central Plant 2812 Chiller Operational Observations and Testing

The chiller, pumps, and cooling tower operate 24 hours a day at a chilled water supply temperature of 40°F to 42°F. The single cell, single-speed cooling tower fan cycles to maintain a condenser supply temperature at 78°F. Because of faulty taps and valves, pressure drop readings could not be taken across the condenser or the evaporator. The cooling tower did not have any obvious defects.

Comments on the plant:

- Both the chilled and the condenser water pumps need to be realigned and grouted.
- The insulation on both chilled and condenser water pipes was in poor condition.
- Pressure taps on chilled and condenser water pipes need to be checked and replaced as needed.

Recommended operating instructions are provided in Section 6.0, including detailed instructions on how the chiller, setpoints, and pumps should operate under given circumstances. Appendix C.1 provides the results of the chiller testing for Central Plant 2812. The chiller efficiency test results for the chiller were:

- Chiller 1: 0.82 kW per ton.

2.2.3.2 Central Plant 2812 Boiler Operational Observations and Testing

The capacity of boiler 1 is 1.80 MMBtu, and the capacity of boilers 2 and 3 is 3.95 MMBtu each. Boiler 1 is a low pressure steam boiler; the other two boilers are hot water boilers. Boiler 1 has a forced-draft burner. Boilers 2 and 3 have atmospheric burners, with two firing stages. Boiler 2 is configured as a leading boiler, while boiler 3 is a lag boiler. Boiler 1 is controlled by a supply steam pressure setting of 12 psig. Boilers 2 and 3 are controlled by supply water temperature settings of 190°F.

To provide heating, boiler 2 typically operates on mild winter days, and boilers 2 and 3 on cold winter days. Boiler 2 operates during the summer for DHW; boiler 1 operates year-round. Two hot water pumps, configured in parallel, circulate hot water in the hot water distribution system. These pumps operate continuously during the heating season, and one pump operates year-round.

The boilers are monitored weekly by the operators; no log of the boilers is kept. The boiler efficiency test results for the three boilers were:

- Boiler 1 79.7% efficiency
- Boiler 2 71.5% efficiency
- Boiler 3 74.0% efficiency.

Appendix C.2 provides the results of the boiler testing for Central Plant 2812.

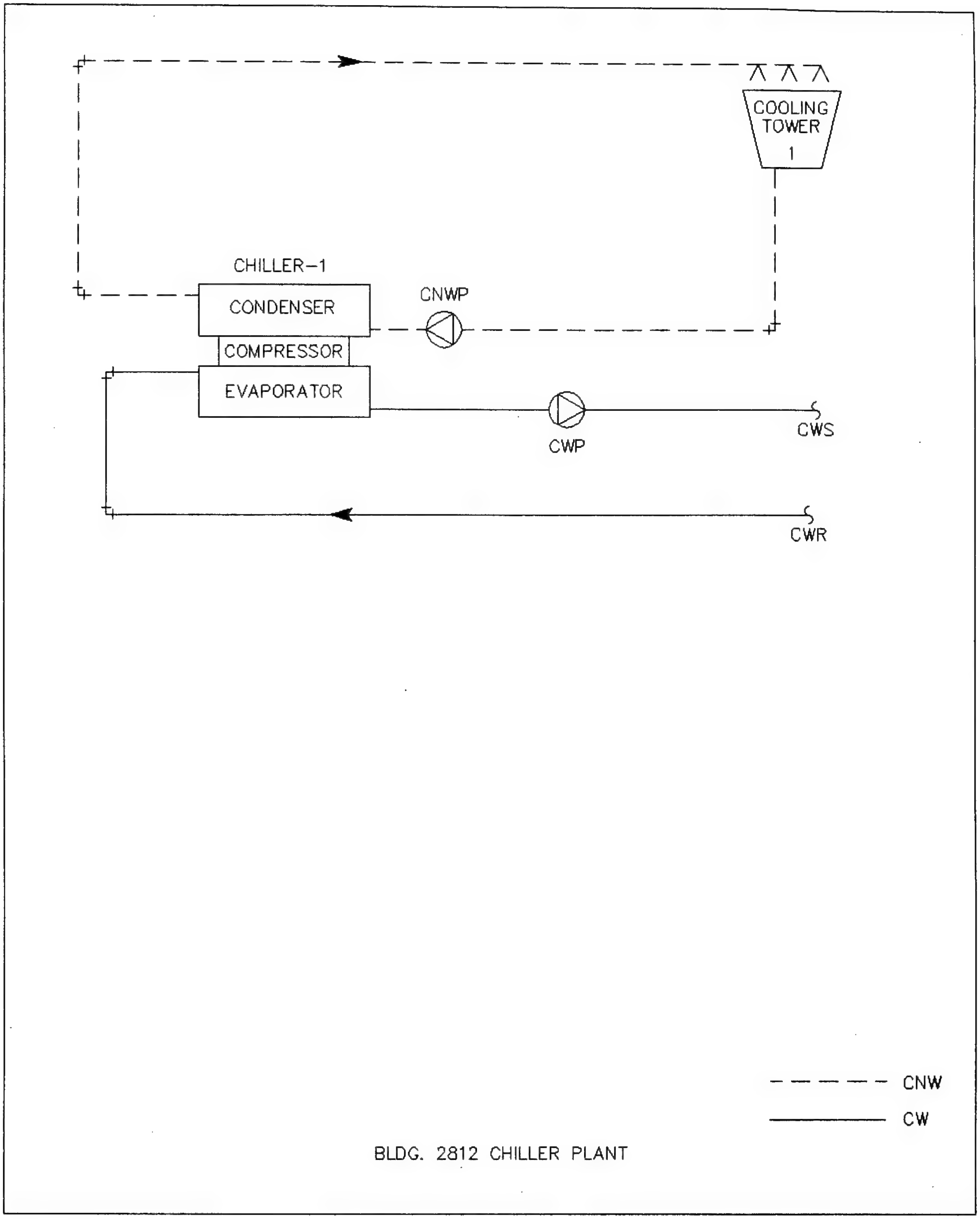


FIGURE 2-7. SCHEMATIC OF CHILLERS, CENTRAL PLANT 2812

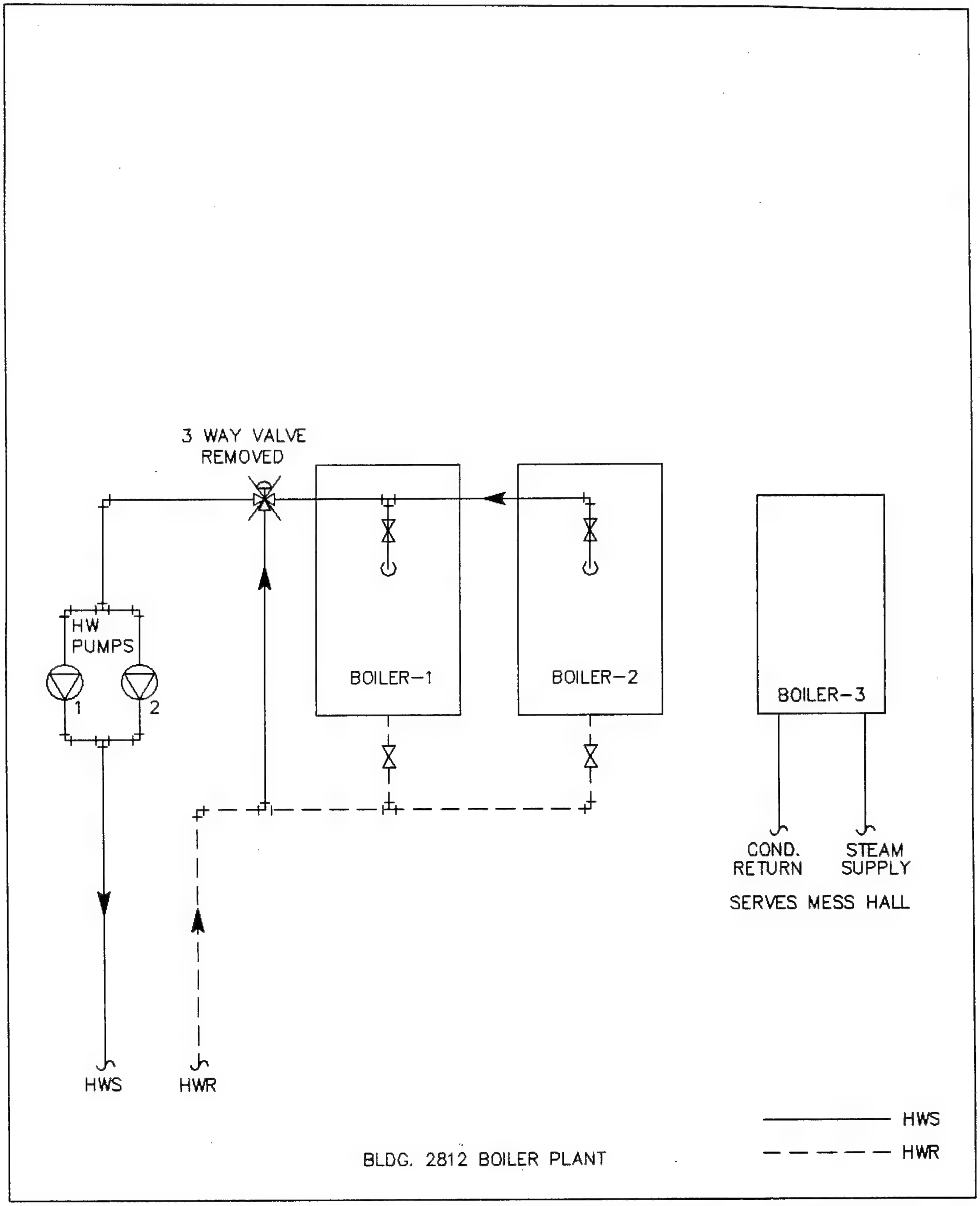


FIGURE 2-8. SCHEMATIC OF BOILERS, CENTRAL PLANT 2812

2.2.4 Central Plant 3442

Central Plant 3442 was renovated in 1987. The central plant has two centrifugal chillers (600 tons each), serving a total of 21 buildings with a nominal design capacity of 1,200 tons cooling. See Appendix E for a detailed listing of all chiller-related equipment. Table 2-1 on page 2-42 lists buildings connected to the central plant. Table 2-2 on page 2-45 lists the major equipment for Central Plant 3442. Figure 2-9 on page 2-21 schematically depicts the piping of the chillers.

2.2.4.1 Central Plant 3442 Chiller Operational Observations and Testing

Both chillers, both chilled water pumps, both condenser water pumps, and both cooling towers are operated during summer months. A Trane TRACER cycles the cooling tower fans, and stages the chiller loading and unloading (the units were in manual operation during the survey). The chilled water setpoint is 45°F. On hot days, water comes back at 52°F. There is a four-cell cooling tower with four single-speed fan motors.

During previous surveys of buildings served by this plant, it was noted there are hot buildings at the end of the distribution system and cold buildings nearest the central plant, indicating balance and flow problems.

Comments on the plant:

- Chillers had no special problems noted.
- Chilled water pumps had no special problems noted; both are horizontal split case with grouted base.
- Condenser water pumps had no special problems noted.
- Cooling tower had the following problems:
  - The fill has heavy deposits and needs to be cleaned.
  - The upper basin is not balanced (water levels not even).
  - Covers on upper basins were removed and should be replaced.
  - Loose deposits in the upper basin block the water distribution orifices.
  - Water levels in the lower basin are not up to the normal operating level, causing air to bypass between cells; these levels should be raised.
  - Fans 1 and 4 start with an abnormally loud noise.

Recommendations:

- Cover upper basins
- Balance upper basins
- Raise water levels in lower basins
- Clean deposits from fill.

Recommended operating instructions are provided in Section 6.0, including detailed instructions on how the chiller, setpoints, and pumps should operate under given circumstances. Appendix C.1 provides the results of the chiller testing for Central Plant 3442. The chiller efficiency test results for the two chillers were:

- Chiller 1: 0.68 kW per ton
- Chiller 2: 0.61 kW per ton.

2.2.4.2 Central Plant 3442 Boiler Operational Observations and Testing

Central Plant 3442 has no boiler.

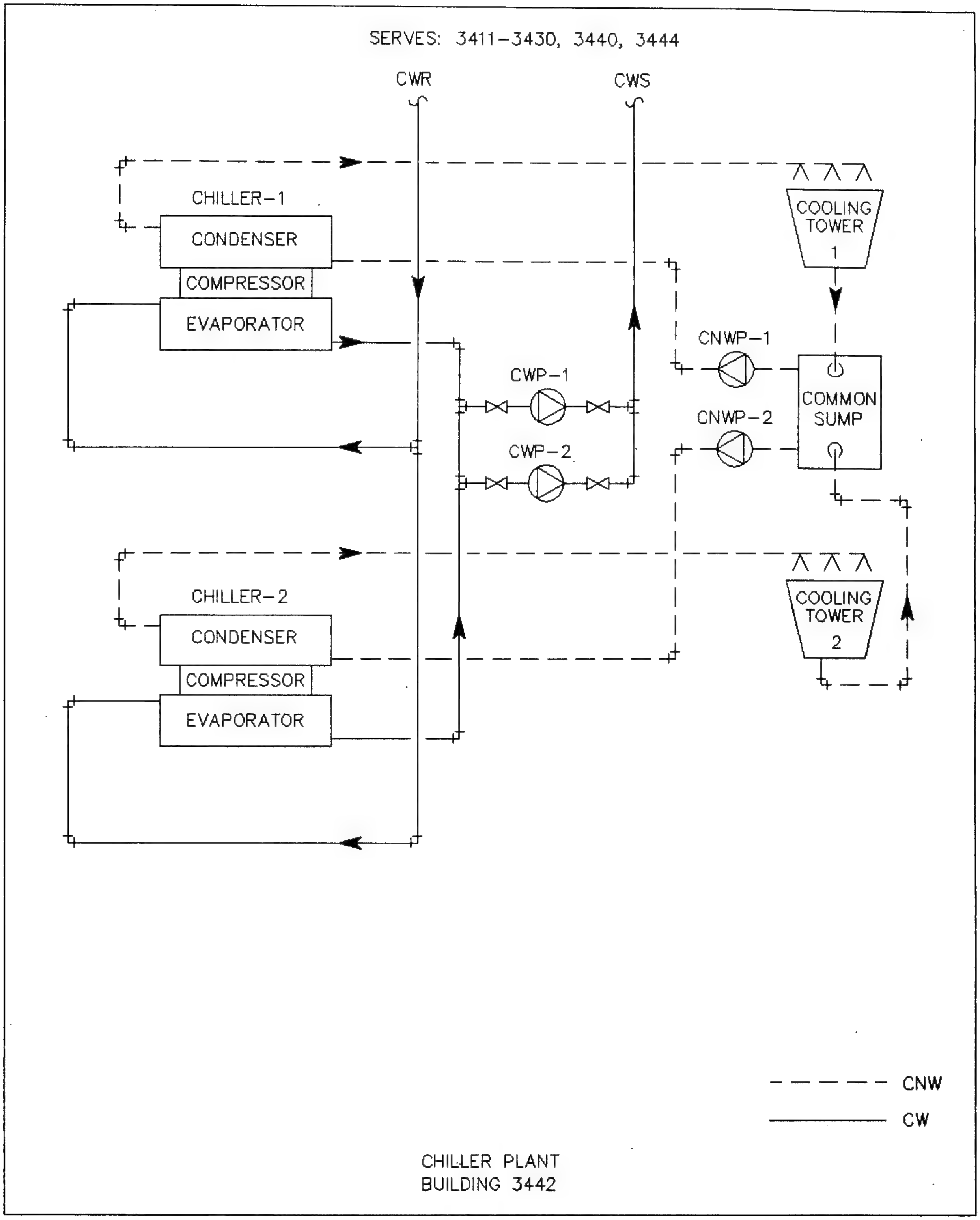


FIGURE 2-9. SCHEMATIC OF CHILLERS, CENTRAL PLANT 3442

2.2.5 Central Plant 4701

Central Plant 4701 and the hospital it serves were constructed in 1962. The central plant has two centrifugal chillers and three high pressure steam boilers. One of the original cooling towers was replaced in 1979. The central plant serves one building and has a nominal design capacity of 610 tons cooling and 33 MMBtu heating. See Appendix E for a detailed listing of all chiller-related equipment and Appendix F for a detailed listing of all boiler-related equipment. Table 2-1 on page 2-42 lists buildings connected to the central plant. Table 2-2 on page 2-45 lists the major equipment for Central Plant 4701. Figures 2-10 and 2-11 on pages 2-24 and 2-25 schematically depict the piping of the boilers and chillers.

2.2.5.1 Central Plant 4701 Chiller Operational Observations and Testing

Both chillers serving the hospital, Building 4700, are operated from May to September, and only one chiller is required from fall to spring. Mechanically, chiller 1 seemed to perform well, but electrical readings and a small chilled water TD resulted in a low calculated efficiency.

Chiller 2 surged badly when loaded to 90% current. Under loaded operating conditions, this chiller hunted every 20 seconds. The pressure drop across the condenser could not be measured because the gauge on the return side is clogged. In testing chillers 1 and 2, no attempt was made to create an artificial full load for the central plant, because of the critical conditions of the hospital.

Comments on the plant:

- Chiller 1 was able to operate at only a fraction of its rated capacity.
- The base of the new chilled water pump should be grouted.
- The steam tracer line to the cooling towers was no longer operational.
- The condenser water pipes were heat traced (electrical resistance heat tape).
- The insulation on condenser water pipes was in poor condition.
- The cooling tower was reported to have freezing problems during the winter.

Recommended operating instructions are provided in Section 6.0, including detailed instructions on how the chillers, setpoints, and pumps should run under given circumstances. Appendix C.1 provides the results of the chiller testing for Central Plant 4701. The chiller efficiency test results for the two chillers were:

- Chiller 1: 1.31 kW per ton
- Chiller 2: 0.73 kW per ton.

2.2.5.2 Central Plant 4701 Boiler Operational Observations and Testing

Three boilers in Central Plant 4701 provide heat to Building 4700. The capacity of each of the three boilers is 11.0 MMBtu. These boilers are high-pressure steam boilers generating 100 psig steam. All three boilers have forced-draft burners. Boiler 1 and 3 operated properly during testing. However, Boiler 2 did not operate during testing because of boiler control failure.

Typically, two boilers operate during the winter and one boiler operates during the summer. These boilers are capable of burning No. 2 fuel oil as an alternate source of fuel. However, the fuel burning apparatus was not operable.

The boilers are monitored hourly by the operators, one of whom runs the central plant during the day, five days a week; an hourly log of the boilers is kept during the day. The boiler efficiency test results for the three boilers were:

- Boiler 1 79.2% efficiency
- Boiler 2 (not operative)
- Boiler 3 79.2% efficiency.

Appendix C.2 provides the results of the boiler testing for Central Plant 4701.

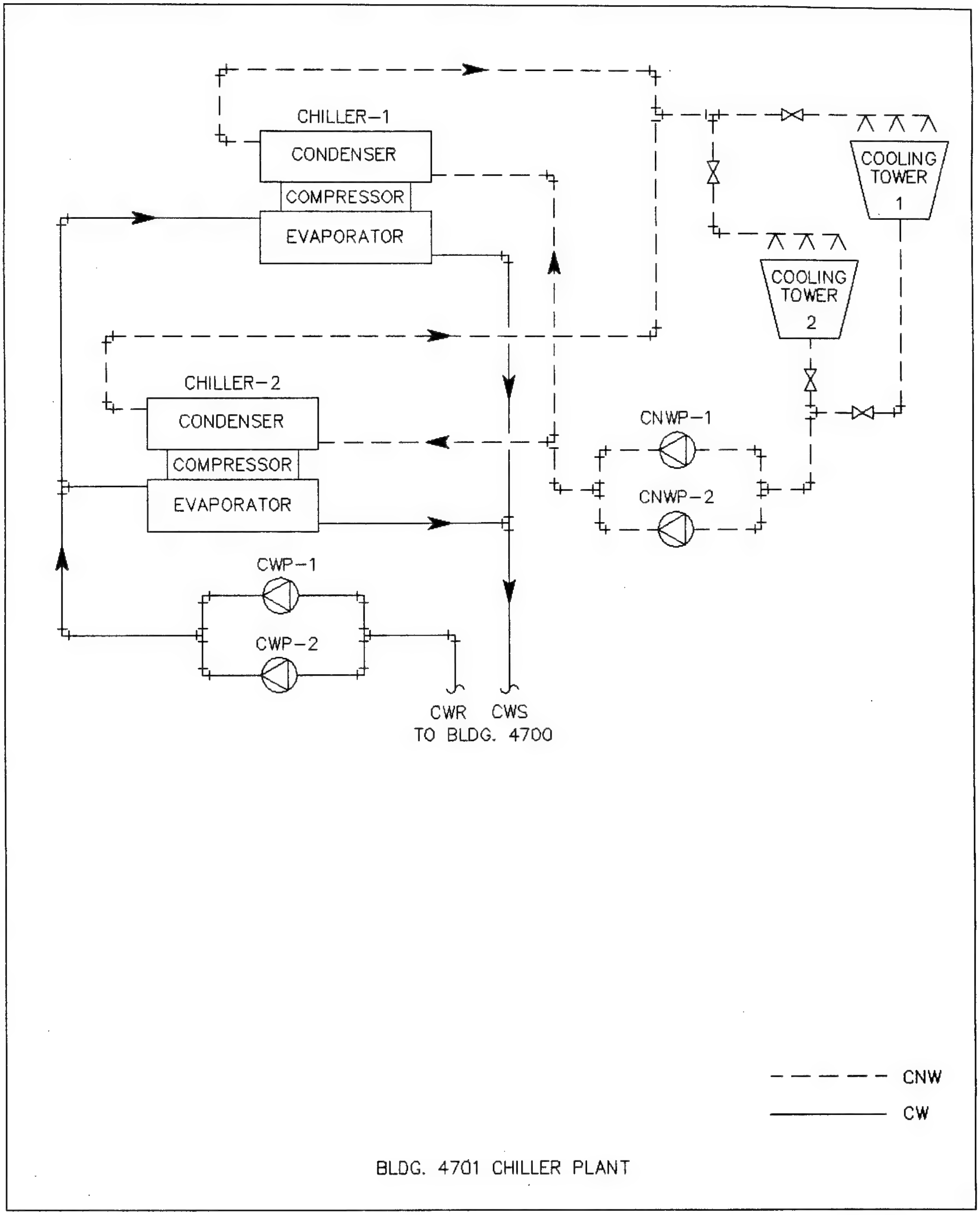


FIGURE 2-10. SCHEMATIC OF CHILLERS, CENTRAL PLANT 4701

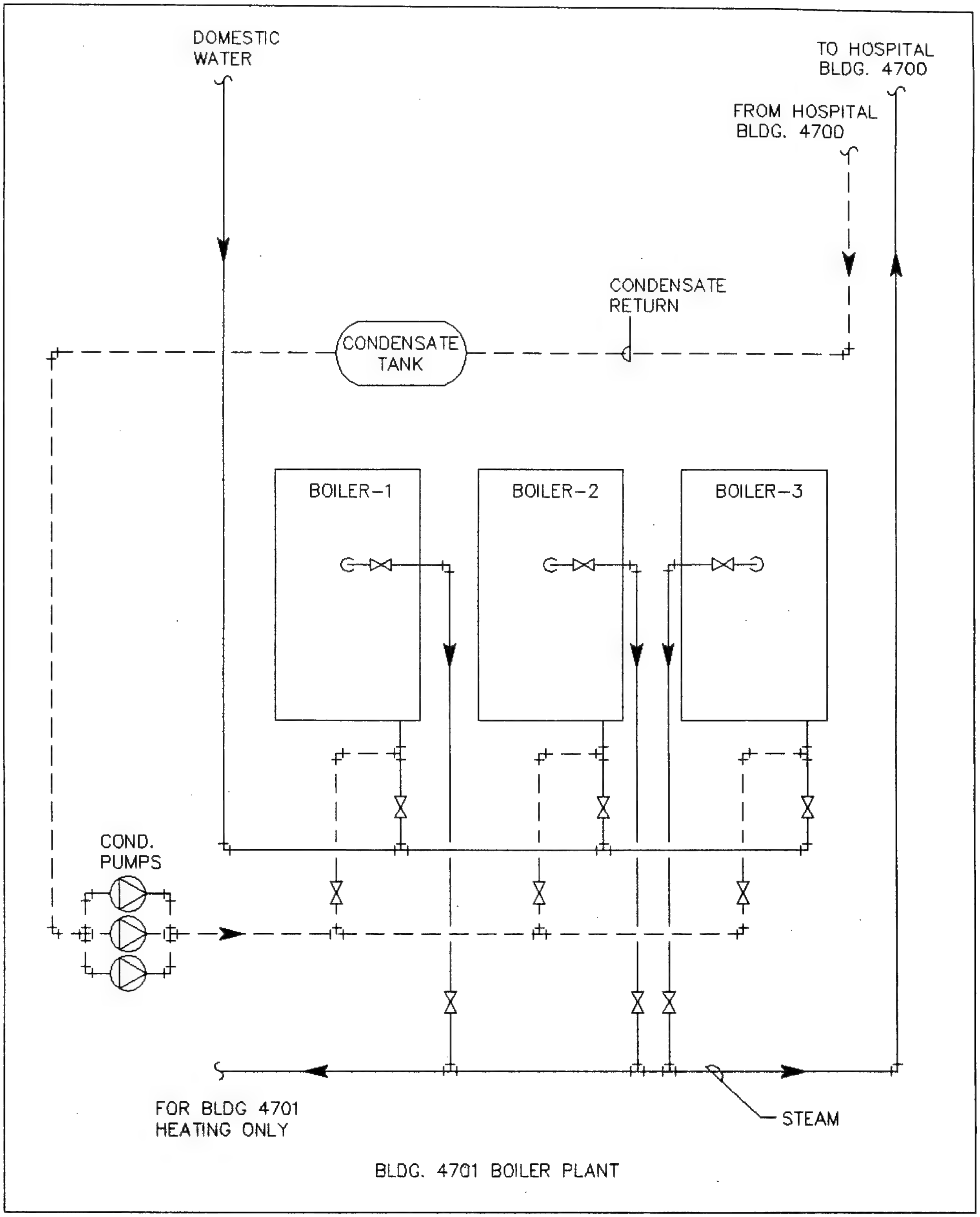


FIGURE 2-11. SCHEMATIC OF BOILERS, CENTRAL PLANT 4701

2.2.6 Central Plant 5676

Central Plant 5676 was constructed in 1967. The central plant, which has one centrifugal chiller and two LTHW boilers, serves only Building 5676 and has a nominal design capacity of 170 tons cooling and 4.88 MMBtu heating. The original chiller was replaced in 1972. See Appendix E for a detailed listing of all chiller-related equipment and Appendix F for a detailed listing of all boiler-related equipment. Table 2-1 on page 2-42 lists buildings connected to the central plant. Table 2-2 on page 2-45 lists the major equipment for Central Plant 5676. Figures 2-12 and 2-13 on pages 2-28 and 2-29 schematically depict the piping of the boilers and chiller.

2.2.6.1 Central Plant 5676 Chiller Operational Observations and Testing

The chiller, chilled water pump, condenser water pump, and cooling tower operate continuously during the summer. The main operator in charge of this building was out during the period of the survey. A pressure drop of 14 psig was measured across the evaporator. This measurement is 4 psig greater than the rated maximum, which could be a sign of clogged or fouled evaporator tubes. If so, these clogged tubes may be the cause of the poor tested efficiency. The cooling tower is equipped with a single-speed fan which cycles to maintain condenser water temperature at the setpoint of 80°F.

Comments on the plant:

- The chiller had a high pressure drop across the evaporator.
- The chilled water pump should be grouted.
- The cooling tower was in poor condition. Many of the orifice holes in the upper basin of the tower were clogged with debris, causing poor circulation.

Recommended operating instructions are provided in Section 6.0, including detailed instructions on how the chiller, setpoints, and pumps should operate under given circumstances. Appendix C.1 provides the results of the chiller testing for Central Plant 5676. The efficiency test results for the chiller were:

- Chiller 1: 1.53 kW per ton.

2.2.6.2 Central Plant 5676 Boiler Operational Observations and Testing

Two boilers in Central Plant 5676 provide heat for the building. Boilers 1 and 2 are hot water boilers, with a rated output capacity of 2.44 MMBtu each. Both boilers have forced draft burners. Boiler 1 is configured as a leading boiler, and boiler 2 is a lag boiler. Both boilers are controlled at a supply temperature setting of 168°F.

Typically, boiler 1 operates on mild winter days, and both boilers 1 and 2 operate on cold winter days, to provide heating. Two hot water pumps, configured in parallel, circulate hot water to the building. These pumps run continuously in the heating season.

The boilers are monitored weekly by the operators; no log of the boilers is kept. The boiler efficiency test results for the two boilers were:

- Boiler 1 75.1% efficiency
- Boiler 2 71.4% efficiency.

Appendix C.2 provides the results of the boiler testing for Central Plant 5676.

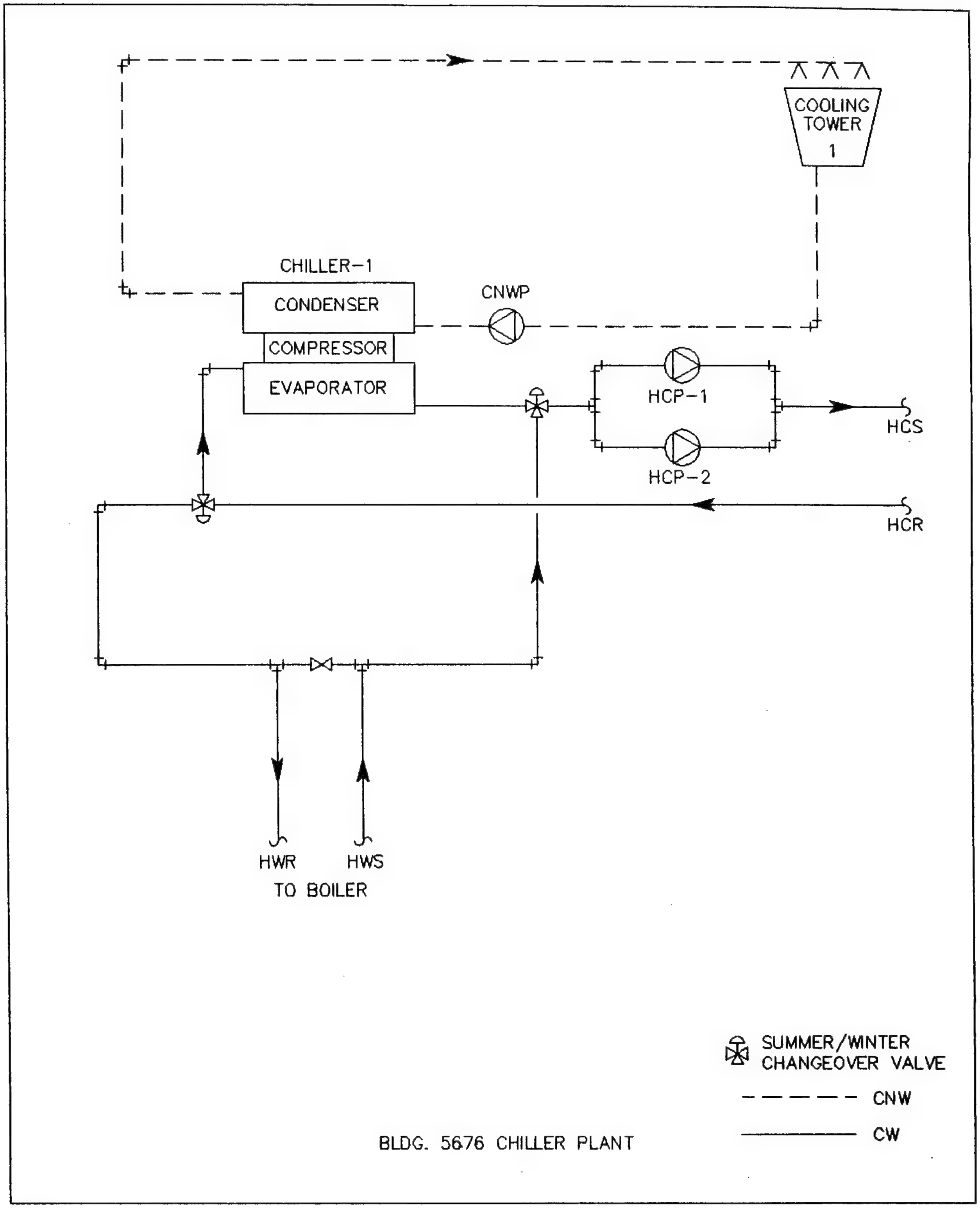


FIGURE 2-12. SCHEMATIC OF CHILLERS, CENTRAL PLANT 5676

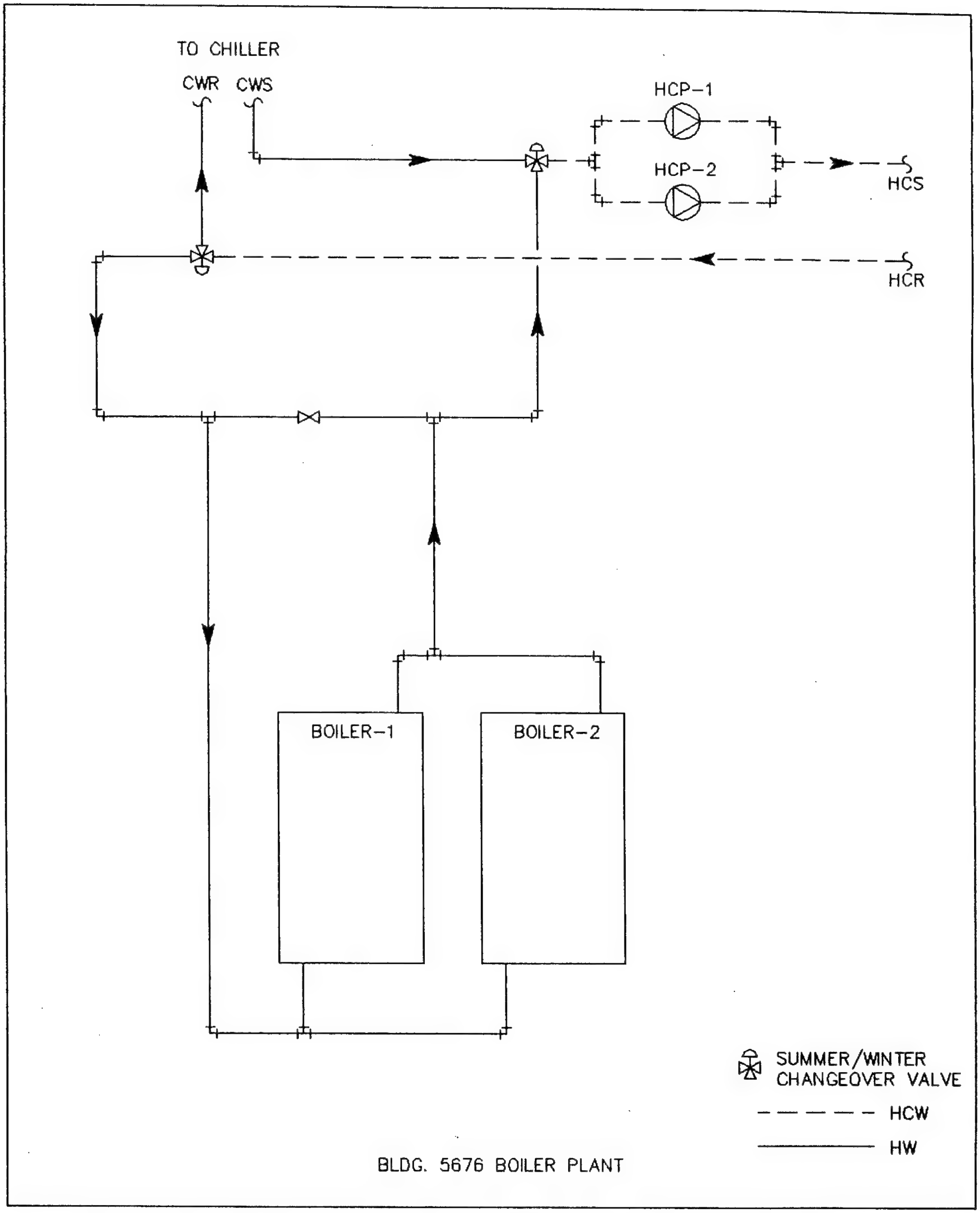


FIGURE 2-13. SCHEMATIC OF BOILERS, CENTRAL PLANT 5676

2.2.7 Central Plant 5678

Central Plant 5678 was constructed in 1967. The central plant has one centrifugal chiller and two LTHW boilers. The original chiller was replaced in 1985. The central plant serves only Building 5678 only and has a nominal design capacity of 190 tons cooling and 4.54 MMBtu heating. See Appendix E for a detailed listing of all chiller-related equipment and Appendix F for a detailed listing of all boiler-related equipment. Table 2-1 on page 2-42 lists buildings connected to the central plant. Table 2-2 on page 2-45 lists the major equipment for Central Plant 5678. Figures 2-14 and 2-15 on pages 2-32 and 2-33 schematically depict the piping of the chiller and boilers.

2.2.7.1 Central Plant 5678 Chiller Operational Observations and Testing

The chiller, chilled water pump, condenser water pump, and cooling tower, operate continuously in the summer. The main operator in charge of this building was out during the period of the survey. During the test, EMC tried setting the chilled water setpoint to 40°F and the current limit to 100%. When the chiller tried to load it started to surge and would not load more than about 4° delta T without surging. The cooling tower has a single-speed fan which cycles to maintain condenser water temperature setpoint.

Comments on the plant:

- The chiller was able to operate at only a fraction of its rated capacity.
- The chilled water pump was in poor condition, with the pump seals leaking badly.
- Condenser water pump had no special problems noted.
- Cooling tower had no special problems noted. The water treatment system was not operational.

Recommended operating instructions are provided in Section 6.0, including detailed instructions on how the chiller, setpoints, and pumps should operate under given circumstances. Appendix C.1 provides the results of the chiller testing for Central Plant 5678. The efficiency test results for the chiller were:

- Chiller 1: 0.68 kW per ton.

2.2.7.2 Central Plant 5678 Boiler Operational Observations and Testing

Two boilers in Central Plant 5678 provide heat for the building. Boilers 1 and 2 are hot water boilers, with a rated output capacity of 2.27 MMBtu each. Both boilers have forced draft burners. Boiler 1 is configured as a leading boiler, and boiler 2 is a lag boiler. Both boilers are controlled by a supply temperature setting of 168°F.

To provide heating, boiler 1 typically operates on mild winter days, and both boilers 1 and 2 operate on cold winter days. Four chilled and hot water pumps, configured in parallel, circulate chilled and hot water to the building. The operators manually switch these pumps from cooling to heating. These pumps operate continuously in the cooling and heating seasons.

The boilers are monitored weekly by the operators; no log of the boilers is kept. The boiler efficiency test results for the two boilers were:

- Boiler 1 67.5% efficiency
- Boiler 2 73.3% efficiency.

Appendix C.2 provides the results of the boiler testing for Central Plant 5678.

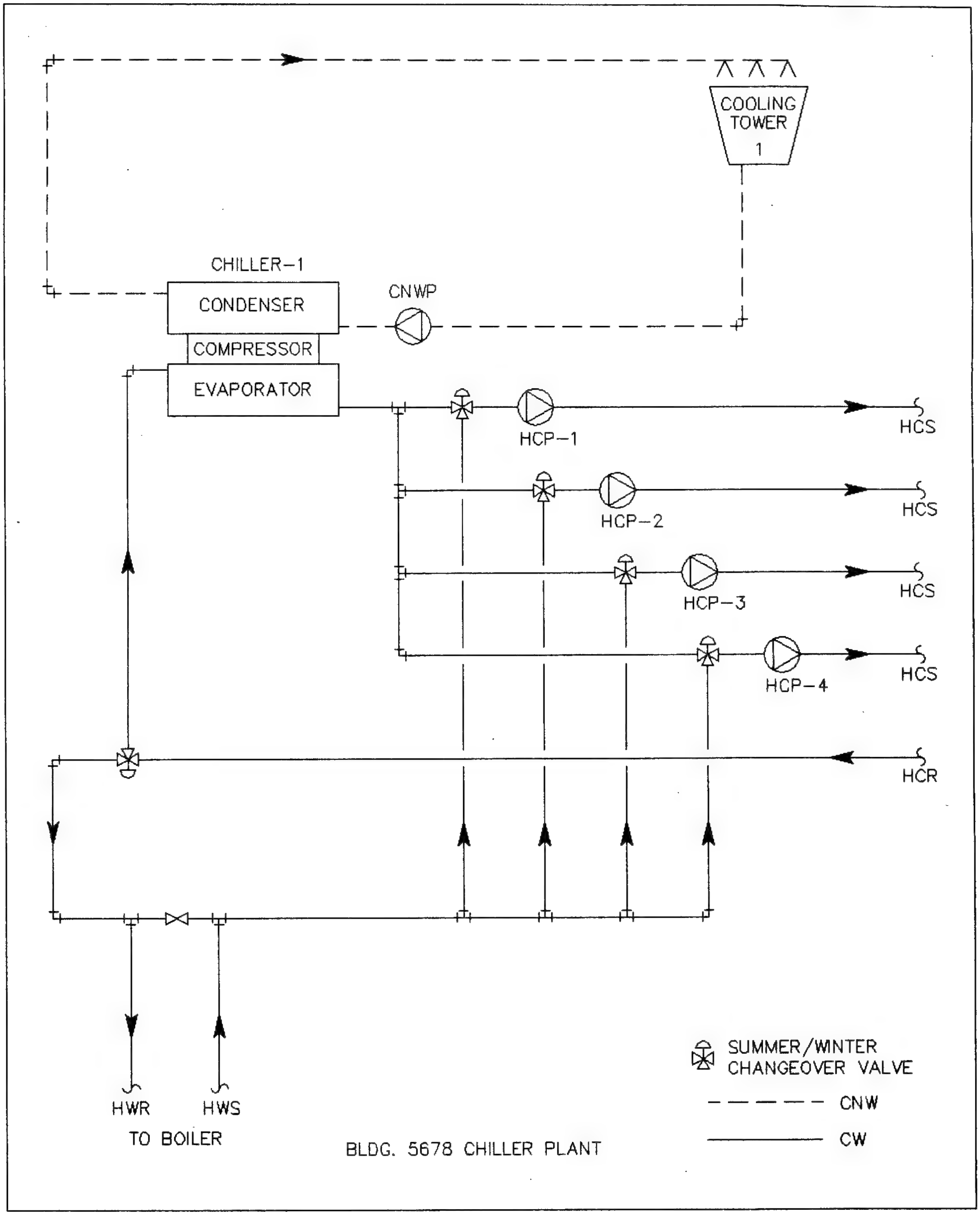


FIGURE 2-14. SCHEMATIC OF CHILLERS, CENTRAL PLANT 5678

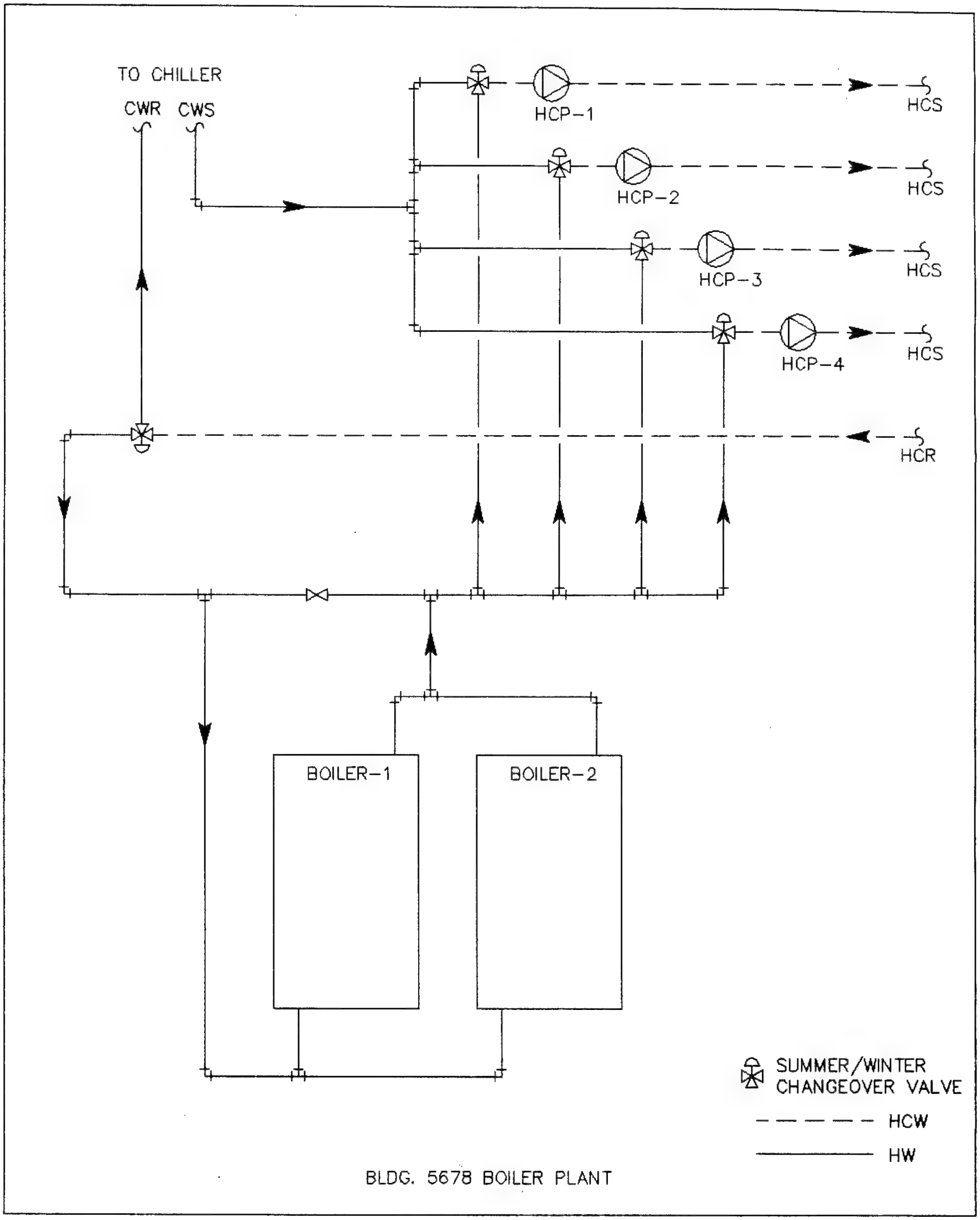


FIGURE 2-15. SCHEMATIC OF BOILERS, CENTRAL PLANT 5678

2.2.8 Central Plant 5900

Central Plant 5900 was constructed in 1978. Four chillers and four boilers were added later, serving a total of five buildings. The central plant now has a total of five centrifugal chillers and six high temperature hot water (HTHW) generators, with a nominal design capacity of 2,050 tons cooling and 58.6 MMBtu heating. See Appendix E for a detailed listing of all chiller-related equipment and Appendix F for a detailed listing of all boiler-related equipment. Table 2-1 on page 2-42 lists buildings connected to the central plant. Table 2-2 on page 2-45 lists the major equipment for Central Plant 5900. Figures 2-16 and 2-17 on pages 2-36 and 2-37 schematically depict the piping of the chillers and boilers.

2.2.8.1 Central Plant 5900 Chiller Operational Observations and Testing

In the summer, four or five chillers are operated to maintain a 58°F return temperature. Each chiller is run on manual; operators bring them on and off. According to the operator, extra chilled water pumps are operated at a ratio of one more pump than the number of chillers on line. The differential pressure control on the central chilled water supply and return header was not functional. Control status or control valve positions had not been checked in quite some time.

Cooling towers 2, 3, 4, and 5 run on high speed above 80°F, and on low speed between 78°F and 80°F. Below 78°F, the fans are off, and below 70°F, the three-way valve bypasses the tower. Cooling tower 1 has only a single-speed fan and three-way valve. Cooling towers 2 and 3 have belt drive fans.

No instrumentation is installed to determine the capacity output of the plant. Some thermometers were recently installed for reading the supply and return temperatures in and out of the plant.

Comments on the plant:

- Chillers had no special problems noted.
- Cooling tower 1 is undersized, causing chiller 1 to operate at part-load only.
- Chilled water and condenser water pumps had no special problems noted.
- The two-speed control on cooling tower 2 was not operative, causing the tower to cycle at high-speed only.
- Physically, the cooling towers are in satisfactory condition.

Recommended operating instructions are provided in Section 6.0, including detailed instructions on how the chillers, setpoints, and pumps should operate under given circumstances.

Appendix C.1 provides the results of the chiller testing for Central Plant 5900. The efficiency test results for the five chillers were:

- Chiller 1: 0.90 kW per ton
- Chiller 2: 0.94 kW per ton
- Chiller 3: 0.83 kW per ton
- Chiller 4: 0.92 kW per ton
- Chiller 5: 0.85 kW per ton.

2.2.8.2 Central Plant 5900 Boiler Operational Observations and Testing

The six HTHW boilers in Central Plant 5900 serve five barracks in the area. Each barracks also has its own LTHW boiler which operates during the summer for DHW. These LTHW boilers have a rating of 2.499 MMBtu input and 2.049 MMBtu output each.

These six HTHW boilers provide heating from around November to April. According to the operator, the number of HTHW boilers on line varies, depending on the outside air temperature. Not all boilers are on-line at one time; on mild winter days, two or three boilers cover the heating requirements.

There are six primary HTHW pumps, 1 through 6, with one pump for each boiler. The primary HTHW pump starts when the boiler starts. HTHW pumps, rated at 130 gpm, are driven by 2-hp motors.

The secondary pumping system for the HTHW consists of five HTHW pumps, 7 through 11. The ratings of these secondary HTHW pumps are:

- Pump 7: 130 gpm driven by a 15 hp motor
- Pump 8: 244 gpm driven by a 20 hp motor
- Pump 9: 244 gpm driven by a 20 hp motor
- Pump 10: 130 gpm driven by a 15 hp motor
- Pump 11: 300 gpm driven by a 25 hp motor.

The operators bring the secondary HTHW pumps on as required by load to maintain a return water temperature of 250°F. Logs of these boilers are kept 24 hours a day. The boiler efficiency test results for the six boilers were:

- Boiler 1: 70.9% efficiency
- Boiler 2: 73.2% efficiency
- Boiler 3: 80.0% efficiency
- Boiler 4: 79.6% efficiency
- Boiler 5: 79.2% efficiency
- Boiler 6: 80.8% efficiency.

Appendix C.2 provides the results of the boiler testing for Central Plant 5900.

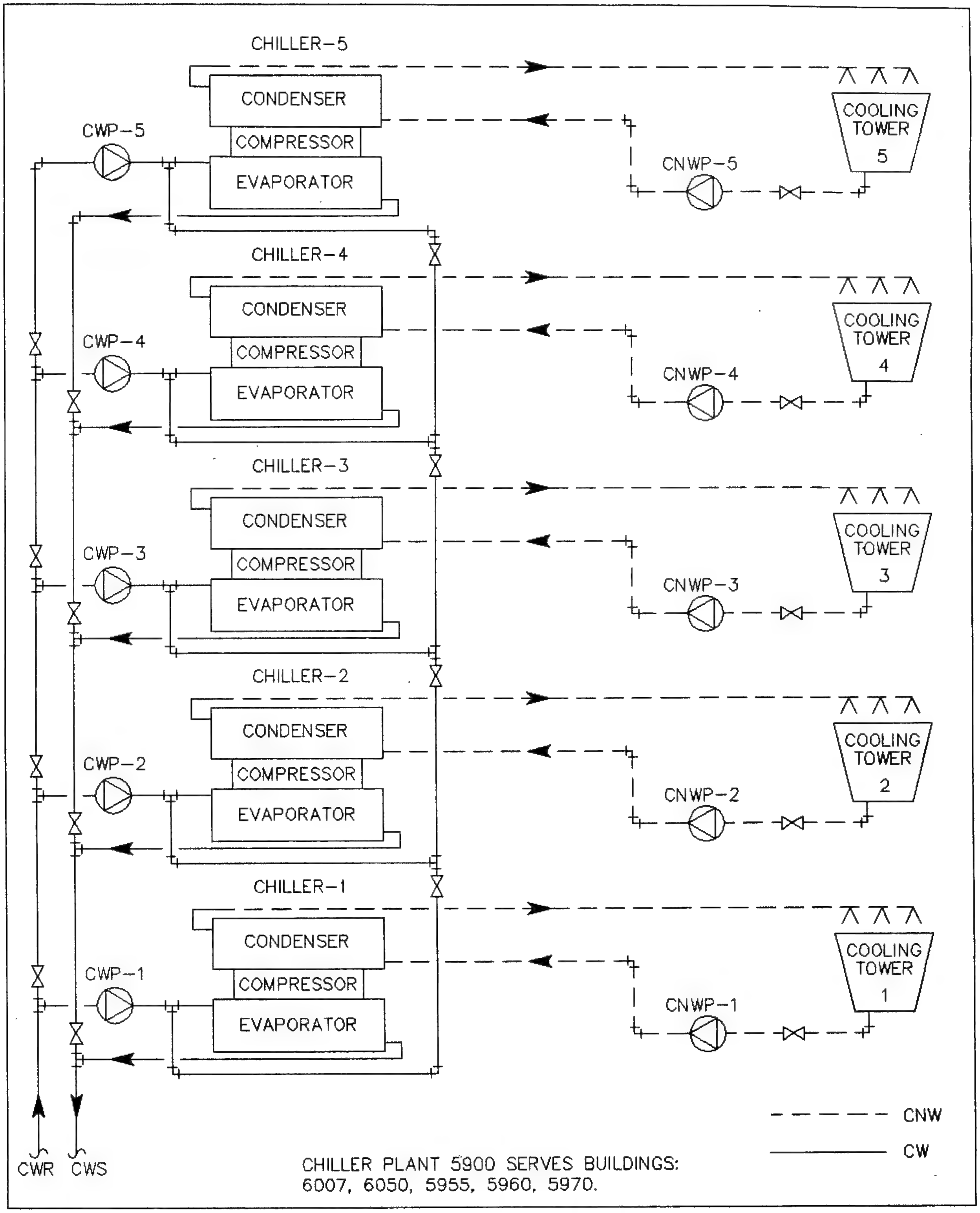


FIGURE 2-16. SCHEMATIC OF CHILLERS, CENTRAL PLANT 5900

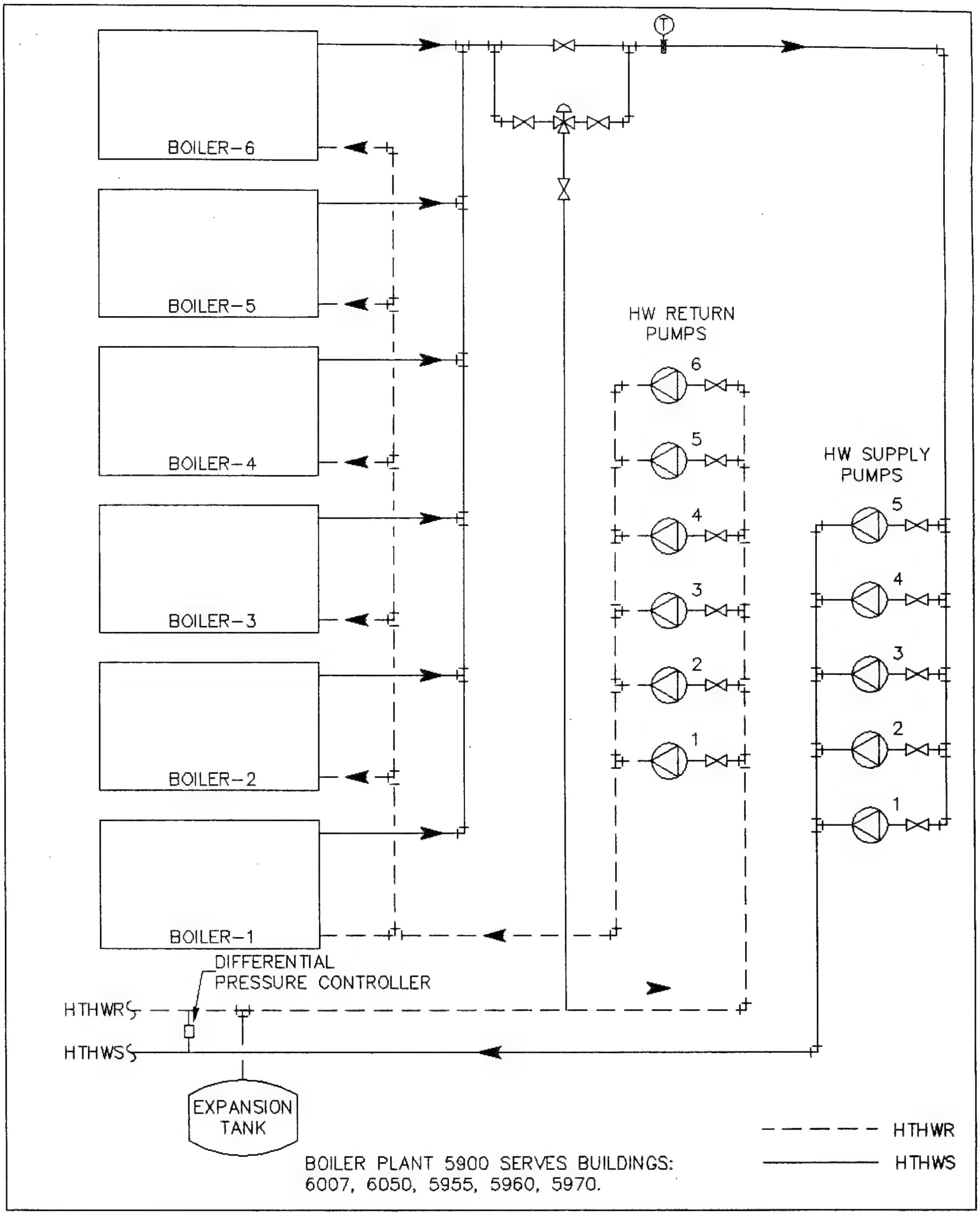


FIGURE 2-17. SCHEMATIC OF BOILERS, CENTRAL PLANT 5900

2.2.9 Central Plant 6003

Central Plant 6003 was constructed in 1972. The central plant, including three centrifugal chillers and three low pressure steam boilers, serves a total of 13 buildings and has a nominal design capacity of 1,300 tons cooling and 35.16 MMBtu heating. A boiler was added in 1990, and two chillers were replaced in 1986. See Appendix E for a detailed listing of all chiller-related equipment and Appendix F for a detailed listing of all boiler-related equipment. Table 2-1 on page 2-42 lists buildings connected to the central plant. Table 2-2 on page 2-45 lists the major equipment for Central Plant 6003. Figures 2-18 and 2-19 on pages 2-40 and 2-41 schematically depict the piping of the boilers and chillers.

2.2.9.1 Central Plant 6003 Chiller Operational Observations and Testing

Chiller 1 (450 tons) is not normally used; for unknown reasons, the chiller would not operate at the time of the survey. Excessive surging preempted testing of chillers 2 and 3 (400 tons each) in the central plant. Chiller 3 would run with the demand limit controller set at 40% or below.

The chilled water piping distribution system was reported to have been repaired this year, and dirt contaminated the chilled water side; however, to keep the system running, the tubes were cleaned mid-summer.

Normally, chillers 2 and 3, chilled water pumps 1 and 2, condenser water pumps 1 and 2, and the large (north) cooling tower, are operated continuously during cooling season.

Cooling tower fan discharges have 1/4 inch mesh screen over the fan guard; this screen should be removed if it is not necessary. The screen will reduce airflow and increase energy consumption due to lowered performance of the cooling tower. Both towers have bypass valves and fan cycle control.

Comments on the plant:

- Chillers 2 and 3 do not operate correctly.
- Chiller 1 will not operate.
- Chilled water and condenser water pumps had no special problems noted.
- The automatic sequencing device is not being used; the chillers are brought on and off manually.
- Cooling tower had no special problems noted.

Recommended operating instructions are provided in Section 6.0, including detailed instructions on how the chillers, setpoints, and pumps should operate under given circumstances.

Appendix C.1 provides the results of the chiller testing for Central Plant 6003. The efficiency test results for the three chillers were:

- Chiller 1: (not operational)
- Chiller 2: (not able to test)
- Chiller 3: (not able to test).

2.2.9.2 Central Plant 6003 Boiler Operational Observations and Testing

The three boilers in Central Plant 6003 are low pressure steam boilers, serving 13 buildings around the area. The rated output capacity of boilers 1, 2, and 3 is 11.72 MMBtu each. All boilers are individual controlled by a supply steam pressure setting of 12 psig.

Typically, either boiler 1 or 2 operates during the winter, and boiler 3 operates during the summer. These boilers are monitored daily by the boiler operator; no log of the boilers is kept.

The boiler efficiency test results for the three boilers were:

- Boiler 1 82.3% efficiency
- Boiler 2 79.8% efficiency
- Boiler 3 (not able to test).

Appendix C.2 provides the results of the boiler testing for Central Plant 6003.

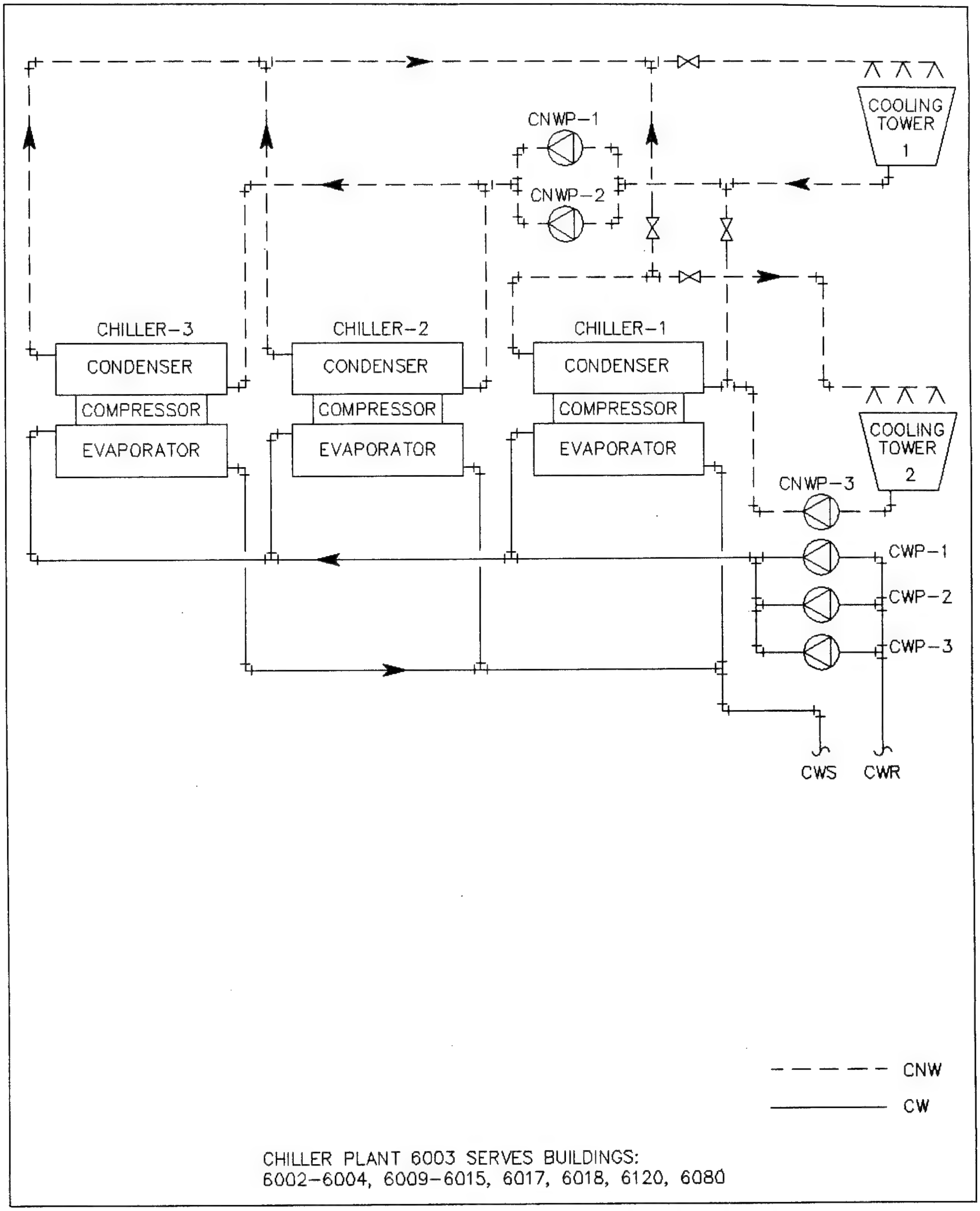


FIGURE 2-18. SCHEMATIC OF CHILLERS, CENTRAL PLANT 6003

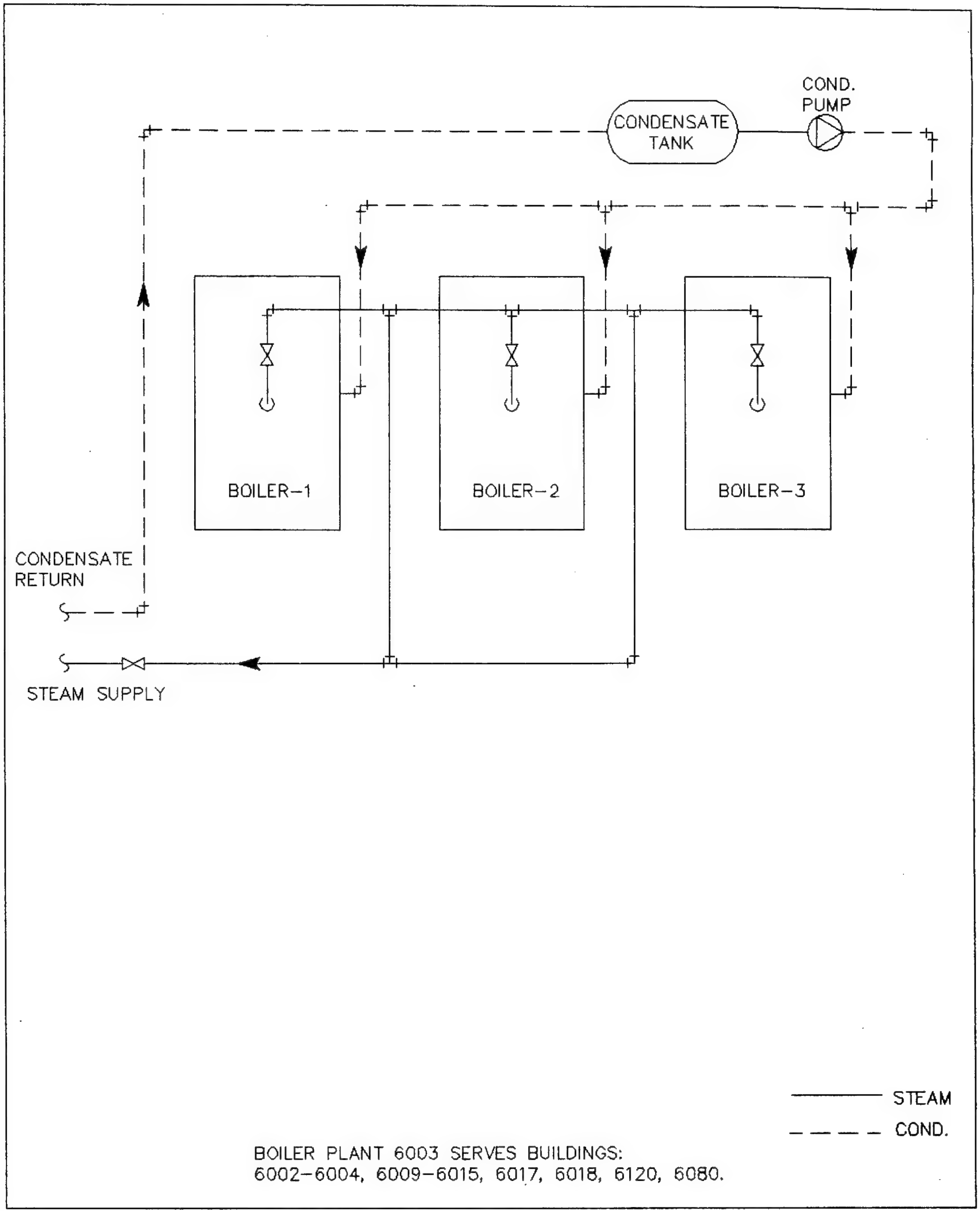


FIGURE 2-19. SCHEMATIC OF BOILERS, CENTRAL PLANT 6003

TABLE 2-1
CONNECTED BUILDINGS AND CONNECTED LOADS

CENTRAL PLANT	BLDG. NO.	BLDG. TYPE	COOLING LOAD	HEATING LOAD	DHW WINTER	DHW SUMMER
730	700	Classroom	X	X	X	X
	707	Classroom	X	X	X	X
	730	Classroom	X	X	X	X
	840	Classroom	X	X	X	X
914	900	Barracks	X			
	912	Barracks	X			
	913	Barracks	X			
	914	Barracks	X	X	X	X
2812	2811	Mess Hall	X	X	X	X
	2838	Barracks	X	X	X	X
	2839	Barracks	X	X	X	X
	2841	Barracks	X	X	X	X
	2842	Barracks	X	X	X	X
	2844	Barracks	X	X	X	X
	2845	Barracks	X	X	X	X
	2846	Barracks	X	X	X	X
	2847	Barracks	X	X	X	X
	2854	Barracks	X	X	X	X
	2856	Barracks	X	X	X	X
	2857	Barracks	X	X	X	X
	2858	Day Room	X	X	X	X
	2859	Barracks	X	X	X	X

TABLE 2-1
CONNECTED BUILDINGS AND CONNECTED LOADS

CENTRAL PLANT	BLDG. NO.	BLDG. TYPE	COOLING LOAD	HEATING LOAD	DHW WINTER	DHW SUMMER
3442	3411	Barracks	X			
	3412	Barracks	X			
	3413	Barracks	X			
	3414	Barracks	X			
	3415	Barracks	X			
	3416	Barracks	X			
	3417	Barracks	X			
	3418	Barracks	X			
	3419	Barracks	X			
	3420	Barracks	X			
	3421	Barracks	X			
	3422	Barracks	X			
	3423	Barracks	X			
	3424	Barracks	X			
	3425	Barracks	X			
	3426	Barracks	X			
	3427	Barracks	X			
	3428	Barracks	X			
	3429	Barracks	X			
	3430	Barracks	X			
	3440	Barracks	X			
4701	4700	Administration	X	X	X	X
5676	5676	Barracks	X	X		
5678	5678	Barracks	X	X		

TABLE 2-1
CONNECTED BUILDINGS AND CONNECTED LOADS

CENTRAL PLANT	BLDG. NO.	BLDG. TYPE	COOLING LOAD	HEATING LOAD	DHW WINTER	DHW SUMMER
5900	5900	Central Plant	X	X	X	
	5955	Barracks	X	X	X	
	5960	Barracks	X	X	X	
	5970	Barracks	X	X	X	
	6007	Barracks	X	X	X	
	6050	Barracks	X	X	X	
6003	6002	Administration	X	X	X	X
	6003	Central Plant	X	X	X	X
	6004	Administration	X	X	X	X
	6009	Barracks	X	X	X	X
	6010	Barracks	X	X	X	X
	6011	Mess Hall	X	X	X	X
	6012	Barracks	X	X	X	X
	6014	Barracks	X	X	X	X
	6015	Barracks	X	X	X	X
	6017	Barracks	X	X	X	X
	6018	Barracks	X	X	X	X
	6080	Store House	X	X	X	X
	6120	Classroom	X	X	X	X

TABLE 2-2
MAJOR CENTRAL PLANT EQUIPMENT

CENTRAL PLANT	BOILER NO.	BOILER SERVICE	BOILER EFF.	BOILER MFG	BOILER (MMBtuh)	CHILLER NO.	TESTED (kW/Ton)	CHILLER MFG	CHILLER (Tons)
730	1	STEAM	NA	KEWANEE	7.75	1	0.89	TRANE	800
	2	STEAM	81.4%	KEWANEE	7.75	3	0.74	TRANE	320
	3	STEAM	81.7%	KEWANEE	7.75	4	NA	TRANE	320
	4	STEAM	81.5%	KEWANEE	2.66				
914	1	STEAM	82.0%	BRUNHAM	1.61	1	1.07	TRANE	400
	2	HW	77.4%	RAY-PAK	1.61				
	3	HW	77.9%	AMERICAN STANDARD	1.92				
	4	HW	74.4%	AMERICAN STANDARD	1.92				
2812	1	HW	71.5%	THERMO-PAK	3.95	1	0.81	CARRIER	370
	2	HW	74.0%	THERMO-PAK	3.95				
	3	STEAM	79.7%	FEDERAL BOILER CO	1.80				
3442	NONE					1	0.68	TRANE	600
	NONE					2	0.62	TRANE	600
4701	1	STEAM	79.2%	BIRCHFIELD	11.00	1	1.14	CARRIER	305
	2	STEAM	NA	BIRCHFIELD	11.00	2	0.97	CARRIER	305
	3	STEAM	79.2%	BIRCHFIELD	11.00				

TABLE 2-2
MAJOR CENTRAL PLANT EQUIPMENT
(Concluded)

CENTRAL PLANT	BOILER NO.	BOILER SERVICE	BOILER EFF.	BOILER MFG	BOILER (MMBtuh)	CHILLER NO.	TESTED (kW/Ton)	CHILLER MFG	CHILLER (Tons)
5676	1	HW	75.1%	AMERICAN STANDARD	2.44	1	1.47	CARRIER	170
	2	HW	71.4%	AMERICAN STANDARD	2.44				
5678	1	HW	67.5%	BRUNHAM	2.27	1	0.71	TRANE	190
	2	HW	73.3%	BRUNHAM	2.27				
5900	1	HTHW	70.9%	INTERNATIONAL	10.00	1	0.92	CARRIER	400
	2	HTHW	73.2%	INTERNATIONAL	10.00	2	0.94	WESTINGHOUSE	400
	3	HTHW	80.8%	HERCULES	9.70	3	0.85	CARRIER	400
	4	HTHW	79.6%	HERCULES	9.70	4	0.94	MCQUAY	450
	5	HTHW	79.2%	INTERNATIONAL	8.00	5	0.85	CARRIER	400
	6	HTHW	80.8%	INTERNATIONAL	11.20				
6003	1	STEAM	82.3%	KEWANEE	11.72	1	NA	TRANE	400
	2	STEAM	79.8%	YORK SHIPLEY	11.72	2	NA	TRANE	450
	3	STEAM	NA	KEWANEE	11.72	3	NA	TRANE	450

SECTION 3.0

ANALYSIS METHODOLOGY

3.1 GENERAL

To perform the economic analysis for the central plants, the following steps were taken:

- Determine the current annual energy consumption on a plant-by-plant basis, as the baseline for evaluating ECOs.

- Estimate the baseline utility and maintenance costs for technically viable ECOs.

- Calculate the utility and maintenance cost savings for each ECO.

- Prepare a cost estimate for the ECO modification.

- Perform a life cycle cost analysis of the ECO to arrive at the SIR.

The following sections discuss in detail the economic factors for the central plant evaluations.

3.2 PLANT EFFICIENCY AND CONSUMPTION CALCULATION METHODOLOGY

The operating information and plant testing information obtained during the field portion of the study were used to calculate the efficiency of each of the boilers and chillers. This information was then used to calculate the base energy consumption for each plant.

Only Central Plant 5900 has log data for chillers or boilers. After evaluating a sample week of information for both boilers and chillers at Central Plant 5900, it was determined that the information was not reliable enough to be useful in preparing energy consumption evaluations.

Because no useful log data exists to calculate energy consumption of the plants, a central plant energy simulation program was used to evaluate the base energy consumption, as well as many of the ECOs discussed in Section 4.0.

The central plant energy simulation program, PC-CUBE, calculates the hour-by-hour energy requirements of a central plant and simulates the resulting energy consumed by each piece of equipment. The hourly load requirements were taken from previous energy evaluations. The program calculates and sums hourly thermal and electrical loads. The energy consumption of each piece of central equipment is determined by simulating equipment response to these hourly load requirements. The program can then be used to evaluate proposed equipment modifications to existing central plants or to make comparisons of equipment and systems for new buildings or plants.

The energy usage and peak loads for each plant were determined by the following methodology:

- The monthly heating and cooling energy usages were taken from computer energy simulations made for representative buildings at Fort Sill, for the Energy Monitoring and Control System (EMCS) study, conducted by EMC Engineers, Inc., at Fort Sill for Tulsa District, under Contract No. DACA 56-90-C-0071.

- The estimated monthly energy usage from the simulations was extrapolated by square foot of building type.

- If one building has more than one type of facility (e.g., administrative, mess hall, and barracks), the monthly energy usage for each type of facility was extrapolated and then added together.

- The distribution losses for heating were manually calculated and added to boiler plant loads. The cooling load for chilled water distribution systems was determined to be negligible for all central plants except Central Plants 5900 and 6003. Central Plants 5900 and 6003 cooling loads, due to distribution losses, were manually calculated and added to chiller plant loads. (See Appendix N for backup calculations.)

- The DHW loads were manually calculated and added to boiler plant loads.

- The monthly peak loads for those months which were determined to have hours above the design temperature (cooling) or below the design temperature (heating), are the sum of the building peak loads, plus the distribution losses.

- The monthly peak loads for those months which were not determined to have hours above the design temperature (cooling) or below the design temperature (heating), are the sum of the building peak loads calculated from the building computer simulations, plus the distribution losses.

- The average number of days for cooling and heating were also input into the program, taken from information provided by Fort Sill for FY81 through FY87:

  - 119 days for cooling per year
  - 174 days for heating per year.

In order to calculate the base energy consumption, the monthly energy usage and peak load values were loaded into PC-CUBE, along with the central plant efficiency curves, auxiliary equipment information, and operating methods. See Section 2.0 for a description of the chiller and boiler testing.

The chiller efficiency and performance calculations are provided in Appendix C.1. The chiller efficiency and performance calculations are based on the following method:

- One set of test data was taken for the chiller, which provided the performance of the chiller at one load point.

- From the nameplate data and test data for the chiller, the estimated percent design kW was calculated for the test point.

- From the rated capacity and tested capacity for the chiller, the percent design capacity was calculated for the test point.

- Based on the percent design capacity and percent design kW, the 100% design kW point was extrapolated from a typical part load performance curve.

- From the 100% kW point, the maximum output capacity was determined, thus providing the estimated performance at 100% capacity.

The chiller part load performance curve, maximum kW input, and maximum capacity output for each chiller were loaded into the PC-CUBE.

The boiler efficiency and performance calculations are provided in Appendix C.2. The boiler efficiency and performance calculations are based on the following method:

- From the boiler stack test data, the combustion efficiency was calculated for low, 50%, 75%, and 100% load points.

- The efficiency of the boiler was compensated for standby and blowdown losses.

- A boiler performance curve was calculated, based on the combustion efficiency and standby and blowdown losses.

The boiler part load performance curve, maximum MBh input, and maximum MBh output for each boiler were loaded into the PC-CUBE.

The methodology used resulted in numbers sufficiently accurate for the purpose of the energy analysis.

3.3 ENERGY SOURCES

Electricity and natural gas are sources of energy which can be conserved by modifying these central plants. These energy sources are discussed below.

3.3.1 <u>Electricity</u>

Electrical energy is supplied to Fort Sill under contract with the United States Department of Energy, Southwestern Power Administration (SWPA). SWPA negotiated the charges for Fort Sill for both the hydroelectric power generated by SWPA, and the thermal electric generated power charges from Public Service Company of Oklahoma. The current rates and contracted amounts are in effect until May 1997.

3.3.1.1 Electrical Demand Charges

Fort Sill has a fixed contracted demand, or "firm capacity," of 36,700 kW per month, at a rate of $2.96 per kW, totaling $108,632 per month. This means it is charged for 36,700 kW every month, 12 months a year, whether or not this is the actual demand. However, Fort Sill cannot exceed 36,700 kW per month during the year without going into a penalty situation.

The contract demand capacity is fixed through May 1997. The penalty for going over the contract demand capacity includes paying $5.45 per kW for the overage, and a 90% ratchet for demand charges the next 11 months. There are also energy penalties involved for overages; the energy penalty is based on Public Service of Oklahoma rate structure "Light and Power (LP2)."

Fort Sill must also pay a demand charge under the thermal electric portion of the bill. This demand charge is for the highest actual demand occurring in the previous 12 months. The rate for the demand charge is $1.787 per kW per month. Fort Sill will see direct savings in demand cost if a modification is performed to reduce the peak summer demand. Any reduction in peak summer demand will result in 12 months of savings, thereafter.

For the central plant study, EMC used $1.787 per kW to calculate the savings from conservation measures.

3.3.1.2 Electrical Energy Charges

The actual charges shown on Fort Sill's electric bill are very, very low. The cost for the hydroelectric federally generated energy is $0.004 per kWh. The cost for the thermally generated energy varies from month to month, with an average charge of $0.0234 per kWh. For months in which Fort Sill incurred thermal energy charges, savings were calculated at the $0.0234 per kWh rate. During months when there were thermal energy charges, savings were calculated at $0.004 per kWh. The average monthly rate used for this study, based on this methodology, was $0.0137 per kWh.

3.3.2 Natural Gas

Natural gas is supplied to Fort Sill by Kansas Louisiana Gas Company and ALG Gas Supply Company of Oklahoma, in Shreveport, Louisiana. Fort Sill purchases gas directly from the supplier and pays a transportation cost for gas to the Fort. The rates for gas are:

- $1.65 per MMBtu, for gas
- $1.27 per MMBtu, for transportation
- $2.92 per MMBtu, total.

3.4 ENERGY CONSUMPTION ANALYSIS

Historical energy usage data at Fort Sill was evaluated so savings figures could be compared with actual consumption.

3.4.1 Electricity

Electrical energy consumption, demand, and costs for FY90 are tabulated in Table 3-1 on page 3-6. The monthly electrical consumption for FY90 varies from a minimum of 9,049,600 kWh in November, to a maximum of 18,376,344 kWh in August. The monthly electrical consumption is illustrated graphically in Figure 3-1 on page 3-7.

TABLE 3-1
ELECTRICAL USAGE AND BILLING

SERVICE MONTHS FY 90	ELECTRICAL ENERGY TOTAL (kWh)	FEDERAL GENERATED ENERGY (kWh)	THERMAL ENERGY (kWh)	ACTUAL DEMAND (kW)	FIRM CAPACITY DEMAND (kW)	THERMAL DEMAND (kW)	FEDERAL GENERATED ENERGY COST ($)	THERMAL ENERGY COST ($)	FEDERAL GENERATED DEMAND COST ($)	THERMAL DEMAND COST ($)	TOTAL ELECTRICAL COST [1] ($)
OCT	10,859,520	9,758,900	1,100,620	20,815.2	36,700	35,641	$39,035.60	$26,965.19	$108,632	$63,690.82	$238,323.61
NOV	9,049,600	4,630,583	4,419,017	17,530.8	36,700	35,641	$18,522.33	$105,406.81	$108,632	$63,690.82	$296,251.96
DEC	10,146,864	0	10,146,864	18,933.6	36,700	35,641	$0.00	$241,251.84	$108,632	$63,690.82	$413,574.66
JAN	11,481,680	7,041,950	4,439,730	18,236.4	36,700	35,641	$28,167.80	$94,339.83	$108,632	$63,690.82	$294,830.45
FEB	9,377,648	9,377,648	0	17,858.4	36,700	35,641	$37,510.59	$0.00	$108,632	$63,690.82	$209,833.41
MAR	10,158,176	10,158,176	0	17,808.0	36,700	35,641	$40,632.70	$0.00	$108,632	$63,690.82	$212,955.52
APR	9,527,263	9,527,263	0	17,740.8	36,700	35,641	$38,109.05	$0.00	$108,632	$63,690.82	$210,431.87
MAY	11,453,400	11,453,400	0	25,880.4	36,700	35,641	$45,813.60	$0.00	$108,632	$63,690.82	$218,136.42
JUN	17,358,264	17,358,264	0	33,843.6	36,700	35,641	$69,433.06	$0.00	$108,632	$63,690.82	$241,755.88
JUL	17,884,272	17,884,272	0	33,339.6	36,700	35,641	$71,537.09	$0.00	$108,632	$63,690.82	$243,859.91
AUG	18,376,344	10,444,935	7,931,409	33,705.0	36,700	35,322	$41,779.74	$199,704.95	$108,632	$63,120.41	$413,237.10
SEP	16,170,504	5,437,224	10,733,280	31,941.0	36,700	33,844	$21,748.90	$240,071.27	$108,632	$60,478.51	$430,930.68
TOTAL	151,843,535	113,072,615	38,770,920	287,633			$452,290	$907,740	$1,303,584	$760,507	$3,424,121

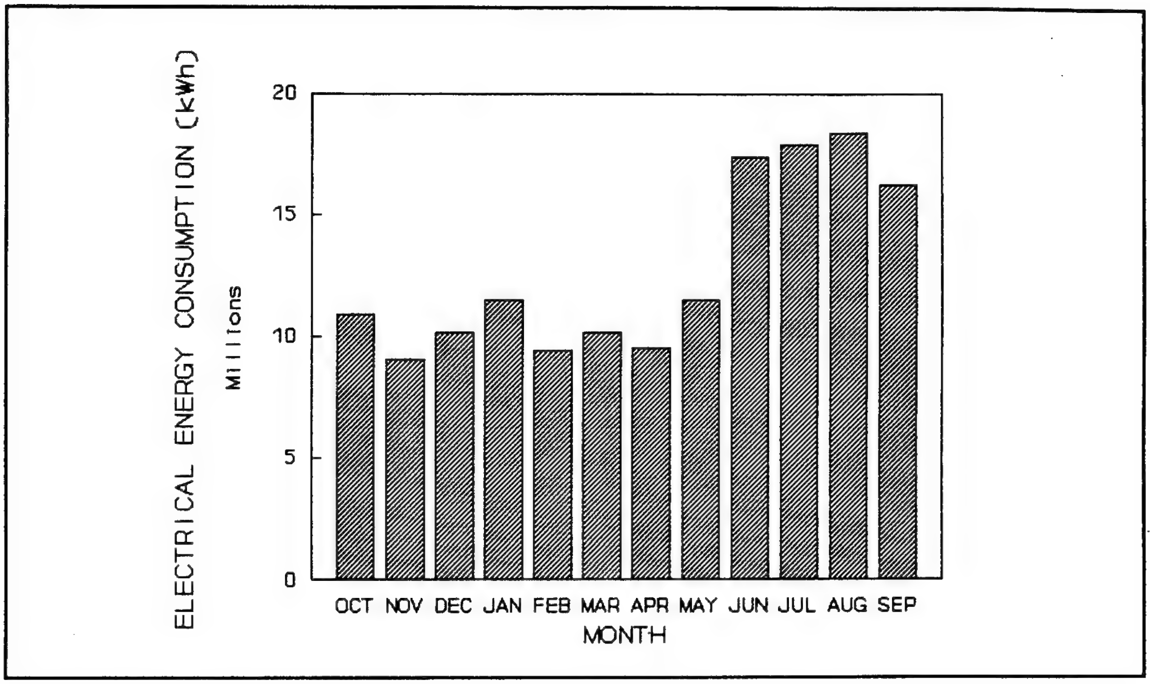


FIGURE 3-1, MONTHLY ELECTRICAL CONSUMPTION

3.4.2 Natural Gas

Natural gas consumption for FY89 is tabulated in Table 3-2 on page 3-8. The monthly natural gas consumption for FY89 varies from a minimum of 21,739 MMBtu in August to a maximum of 222,094 MMBtu in February. The monthly natural gas consumption is illustrated graphically by Figure 3-2 on page 3-9.

TABLE 3-2
NATURAL GAS CONSUMPTION - FY89

Month	MMBtu Consumption
October	38,562
November	108,070
December	163,565
January	173,196
February	222,094
March	135,771
April	50,266
May	29,267
June	26,329
July	26,000
August	21,739
September	31,302
Total	1,026,161

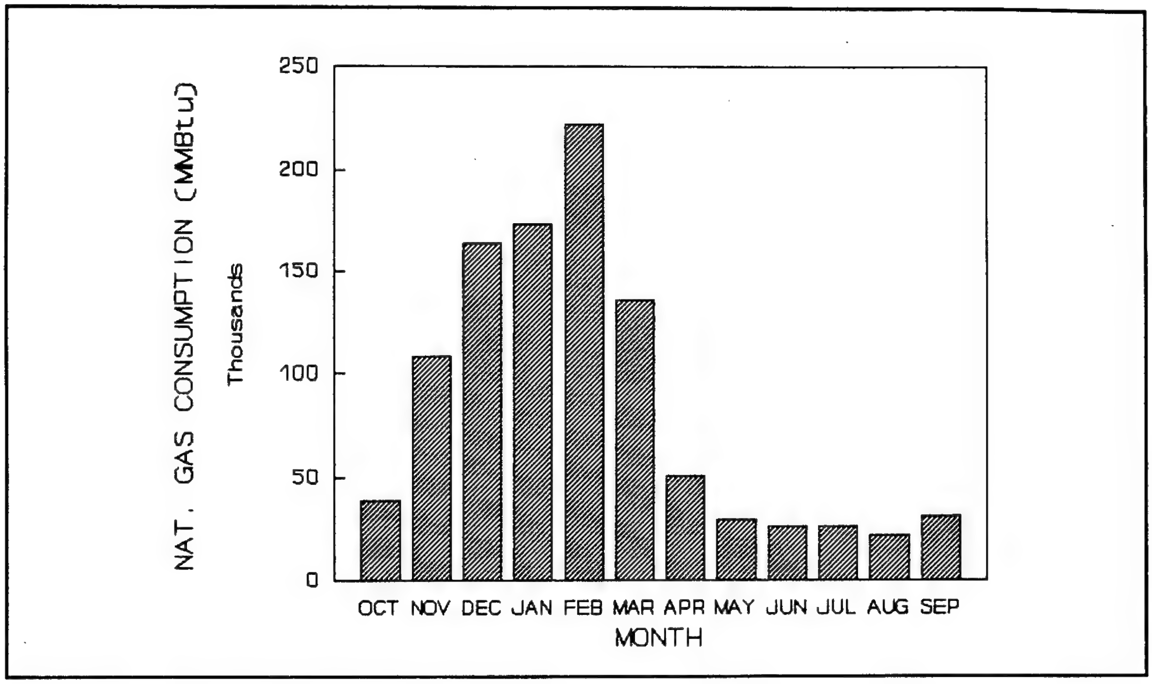


FIGURE 3-2, MONTHLY NATURAL GAS CONSUMPTION

3.5 BASIS FOR ECONOMIC ANALYSIS

3.5.1 ECIP Guidance

The Energy Conservation Investment Program (ECIP) funding program criteria were used to determine project economics. Projects were evaluated using the uniform present worth factors in the November 1988 edition of NISTIR-85/3273-3 (see Table 3-4 on page 3-11).

3.5.2 Basis for Labor and Material Costs

Labor hours required to implement the ECOs were estimated using the Mean's Cost Estimating Manual, 1991 edition. Labor rates are listed in Table 3-3 on page 3-10.

TABLE 3-3
LABOR RATES

Trade-Craft	Rate ($/hr)*
Electrician	$19.60
Pipefitter-Plumber	$24.00

* Note - The above wage rates include fringe benefits.

The following sources were used to develop the cost estimates of materials:

- Standard cost estimating guides
- Actual costs from similar construction projects
- Equipment vendor quotations.

Unit material cost estimates do not reflect quantity discounts which may be possible at the time of the actual installation.

3.5.3 Basis for Energy Cost Savings Benefits

The energy savings for ECOs presented in this report were determined by using the PC-CUBE program, and hand calculations where appropriate. Unit energy costs were calculated from contract information and historical data, to be used with the energy savings in order to estimate the dollar cost avoidance. For electrical savings, the following unit cost was used:

Average electricity charge = $ 0.0137/kWh
($4.01/MMBtu, based on 3,413 Btu per kWh)

For natural gas savings, the following unit cost was used:

Natural gas = $2.92/MMBtu

For maintenance, labor savings, or cost, the following unit cost was used:

Labor time = $12.80/hr.

The Life Cycle Cost in Design (LCCID) program, developed by the U.S. Army Construction Engineering Research Laboratory, was used to calculate life cycle cost benefits.

The maximum economic life and uniform present worth (UPW) factors for natural gas, electricity, and non-energy items for DOE Region 6, from NISTIR-85, are listed in Table 3-4 below.

TABLE 3-4
UNIFORM PRESENT WORTH FACTORS

CATEGORY	MAXIMUM ECONOMIC LIFE	UPW ELECTRICITY	UPW NATURAL GAS	UPW NON-ENERGY
Boiler Plant Modification	25 Years	11.37	17.52	11.65
Energy Recovery System	25 Years	11.37	17.52	11.65
Electrical Energy Systems (Including Chillers & Motor Replacements)	25 Years	11.37	17.52	11.65
HVAC (Including Controls)	15 Years	8.78	12.48	9.11
EMCS	15 Years	8.78	12.48	9.11

SECTION 4.0

EVALUATION OF ENERGY CONSERVATION OPPORTUNITIES

4.1 GENERAL

Using the analysis methodology described in Section 3.0, the base energy usage for each central plant was determined. For each central plant, the technical and economical feasibility was evaluated for all potential ECOs listed in Annex A of the SOW. In addition, a number of special projects were evaluated for specific central plants. The results of the base energy usage and ECO evaluations are presented in the following subsections. Backup data related to the base energy usage is presented in Appendix B, Volume II.

Interrelationships between ECOs were not taken into consideration in the Interim Submittal. Each ECO is evaluated as a stand-alone project. All backup data related to the ECOs are presented in Appendix D, Volume II. In that appendix, page numbers are supplemented by ECO designation and assembled in the same order as the material presented in this section.

Table 4-1, on page 4-2, lists each ECO evaluated in the following sections, along with the ECO number designation. ECOs 1 through 12 were investigated for each central plant. ECOs 13 through 17 are special projects which were evaluated for specific central plants. Table 4-2, on page 4-3, lists each ECO which was evaluated for energy savings potential. Table 4-3, on page 4-4, lists each ECO which was not feasible.

TABLE 4-1
ECO LIST

ECO NUMBER	ECO DESCRIPTION	SPECIAL PROJECT - CENTRAL PLANT NUMBER
1.	Install instrumentation to establish chiller plant load to improve plant operations, thereby saving energy.	
2.	Control systems to match chiller capacity and characteristics with the load, thereby saving energy.	
3.	Renovate or replace chillers to improve efficiency, thereby saving energy.	
4.	Install ice storage cooling system to reduce peak air conditioning electrical demand.	
5.	5(A) - Install two-speed cooling tower fans to reduce cooling tower electrical energy. 5(B) - Install variable-speed cooling tower fans to reduce cooling tower electrical energy.	
6.	Install high efficiency motors, thereby saving electrical energy.	
7.	Install instrumentation to establish boiler plant load to improve plant operations, thereby saving energy.	
8.	Control systems to match boiler capacity and characteristics with the load, thereby saving energy.	
9.	Renovate or replace boilers to improve efficiency, thereby saving energy.	
10.	Install combustion controls to assure proper fuel-to-air ratio; increase combustion efficiency, thereby saving energy.	
11.	Install new high efficiency burners on boilers to increase combustion efficiency, thereby saving energy.	
12.	Install stack economizer or air preheater to recover heat from the boiler stack, thereby saving energy.	
13.	Install chilled water variable speed pumping to improve flow and pressure drop in the distribution system, saving electrical energy.	5900
14.	Install smaller pumps to match flow requirements, saving electrical energy.	730 & 4701
15.	Install a cogeneration, natural gas turbine engine, to generate electricity on-site, saving electrical demand and energy.	6003
16.	Install natural gas driven chillers to save electrical demand and energy.	2812
17.	Install electric boilers in building for summer DHW to shut down central plant in the summer, thereby saving distribution loss and pumping energy.	730 & 2812

TABLE 4-2
ECOs EVALUATED LISTED BY CENTRAL PLANT

ECO NO.	CENTRAL PLANT								
	730	914	2812	3442	4701	5676	5678	5900	6003
1	X			X	X			X	X
2	X			X	X			X	
3	X	X	X		X	X		X	
4	X	X	X	X	X	X	X	X	X
5(A)	X		X			X	X	X	X
5(B)	X	X	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X	X	X
7	X	X	X		X	X	X	X	X
8		X	X				X	X	
9		X	X			X	X	X	
10	X				X	X	X	X	X
11									
12					X	X	X	X	
13								X	
14	X				X				
15									X
16			X						
17	X		X						

TABLE 4-3
ECOs NOT CONSIDERED FEASIBLE

CENTRAL PLANT	ECO NO.	COMMENTS
730	8	No opportunity for boiler optimization.
	9	No opportunity for additional savings with boiler renovation.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.
914	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	5(A)	The cooling tower already has two-speed tower fans.
	10	These burners are non-modulating type. Oxygen trim will not work.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.
2812	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	10	These burners are non-modulating type. Oxygen trim will not work.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.
3442	3	No opportunity for more efficient chillers.
	5(A)	This cooling tower has four cells. It is not feasible to add two-speed control.

TABLE 4-3
ECOs NOT CONSIDERED FEASIBLE

CENTRAL PLANT	ECO NO.	COMMENTS
4701	5(A)	This cooling tower has four cells. It is not feasible to add two-speed control.
	8	No opportunity for boiler optimization.
	11	No high efficiency burners small enough for these boilers.
5676	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	11	No high efficiency burners small enough for these boilers.
5678	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	3	No opportunity for more efficient chillers.
	11	No high efficiency burners small enough for these boilers.
5900	11	No high efficiency burners small enough for these boilers.
6003	2	No opportunity for chiller optimization. Both chillers are the same size and efficiency.
	9	No opportunity for additional savings.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.

4.2 CENTRAL PLANT 730 EVALUATION

4.2.1 Baseline Energy Usage

Using the PC-CUBE program, Central Plant 730 was evaluated to determine the baseline energy usage as the plant currently operates. The baseline calculation considered heating and cooling loads, DHW loads, distribution losses, and plant efficiencies.

The central plant operating procedures taken into account for the baseline calculation include:

- Chiller 1 (800 tons) is operated in the summer months.
- Chiller 3 (300 tons) is operated during spring and fall to serve only Central Plant 730.
- Boilers 1, 2, and 3, are operated in the winter months.
- Boiler 4 is operated in the summer to serve the DHW loads.
- HW distribution pumps operate year-round to circulate water to buildings served.

The evaluation assumed the central plant to be connected to the proposed EMCS currently in design. The run-time hours of the chiller plant will be limited only to those hours required to serve Central Plant 730 cooling loads when facilities are operating, 0600 hours to 1700 hours, Monday through Friday.

The study indicates the 800 ton chiller will operate a significant number of hours at 0% to 30% loading. The same is true for the 300 ton chiller operating in the spring and fall. The boiler loads indicate a peak loading for two boilers in the winter, with the third boiler requiring only a maximum of 50% loading. The majority of operating hours for boiler 4 in the summer are at 20% to 30% loading.

The estimated annual baseline energy consumption and demand for chillers in Central Plant 730 are:

- Total electrical consumption, 819,333 kWh
- Peak electrical demand, 525 kW.

The estimated annual baseline energy consumption for boilers in Central Plant 730 is:

- Total natural gas consumption, 22,568 MMBtu
- Total electrical consumption, 208,939 kWh.

4.2.2 ECO Evaluation

CENTRAL PLANT 730 ECO 1.
INSTALL INSTRUMENTATION TO ESTABLISH CHILLER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the chiller plant.

Chiller plant operators start and stop individual chillers based on their estimate of the daily weather and the chilled water return temperature. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the actual cooling load minimizes the amount of time extra chillers are operated unnecessarily. The energy savings result from:

- The difference in operating efficiency of the chillers operating at lower load than would be the case if they were more fully loaded.
- The difference in operating only the pumps and cooling towers required for the number of chillers to meet the load.

Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The chiller and pump sequence of operation was changed from the sequence used in the baseline, to better match the required load. The energy saved by this ECO is the difference between the baseline and the ECO computer simulations.

Currently, the 800 ton chiller and excess pumping operate during periods when the 300 ton chiller and fewer pumps would satisfy the load.

Results:

Annual Electricity Savings (kWh):	243,000
Peak Electrical Demand Savings (kW):	129
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	\$6,095
Analysis Period:	15 Years
Estimated Construction Cost:	\$5,620
Simple Payback:	0.9 Years
Savings-to-Investment Ratio (SIR):	9.6

Recommendation: Implement.

CENTRAL PLANT 730 ECO 2.
OPTIMIZE CHILLER OPERATION

Premise:
This ECO proposes to optimize chiller sequence of operation. Two chillers with different efficiencies operate to meet the chilled water load. Currently, the larger and less efficient chiller operates more hours than the chiller with the higher efficiency. During the times when both chillers are not required, energy can be saved by operating the more efficient chiller.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The Chiller Identification Numbers were resequenced to simulate starting chillers in a different order.

The energy saved by this ECO is the difference between the baseline and the ECO simulations.

Results:

Annual Electricity Savings (kWh):	338,000
Annual Electrical Demand Savings (kW):	163
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$8,126
Analysis Period:	15 Years
Estimated Construction Cost:	$18,939
Simple Payback:	2.6 Years
Savings-to-Investment Ratio (SIR):	3.5

Recommendation: Implement.

CENTRAL PLANT 730 ECO 3.
INCREASE CHILLER EFFICIENCY

Premise:
This ECO proposes to repair the chiller to obtain a higher efficiency.

The 800 ton chiller operates with an efficiency of 0.89 kW per ton. Design characteristics of the chiller indicate possible performance of 0.73 kW per ton at new condition. Performing minor repairs, cleaning, and other system modifications as necessary will increase the efficiency of the chiller.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Chiller performance data, representing a 10% improvement in efficiency, was entered in place of the tested performance data. The energy saved by this ECO is the difference between the baseline and the ECO simulations.

The cost was based on a one time minor repair project and an annual maintenance contract to maintain chiller operation at peak efficiency.

Results:

Annual Electricity Savings (kWh):	2,000
Peak Electrical Demand Savings (kW):	22
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$499
Annual Maintenance Cost	$3,000
Net Annual Cost Savings	$2,501
Analysis Period:	15 Years
Estimated Construction Cost:	$6,330
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:
Although the analysis indicates this, as an ECO, would not meet ECIP criteria based soley on energy savings, it is strongly recommended that the chiller be repaired, and maintained at optimum efficiency. If not, it will continue to deteriorate, operate even less efficiently, and fail, which will result in major repair or replacement costs.

CENTRAL PLANT 730 ECO 4.
INSTALL ICE STORAGE COOLING SYSTEM

Premise:
This ECO proposes to install an ice storage cooling system to reduce peak air conditioning electrical demand (load shifting) and cost.

The primary advantage of an ice storage cooling system is the ability to use lower time-of-day electricity rates and off-peak demand rates to produce ice which can be used instead of chillers to provide cooling for HVAC equipment during times of peak electrical use. Fort Sill does not have this type of rate structure; however, if the overall peak electrical demand can be reduced by shutting off chillers during peak periods, demand charges can be reduced for the whole year.

Basis for Analysis:
The savings of this ECO were calculated, based on the following assumptions.

- A reduction in chiller use of four hours per day is sufficient to reduce peak electrical demand.
- The reduction in demand will occur simultaneously with the overall base peak electrical demand.
- The auxiliary electrical loads imposed by the ice storage system offset the reduction in chiller auxiliary electrical use.
- The performance penalty due to the chillers producing ice instead of water at normal chilled water temperatures was not taken into consideration (best case scenario).
- The electrical demand savings are $1.787 per kW.

Cost and savings calculations are shown below:

Cost
= Tons capacity x hours per day x $60 per ton-hour
= 800 Tons x 4 hours per day x $60 per ton-hour
= $192,000

(Continued)

CENTRAL PLANT 730 ECO 4. (Continued)
INSTALL ICE STORAGE SYSTEM

Annual Savings
= Tons capacity x kW per ton x $1.787 per kW-month x 12 months per year
= 800 Tons x 0.89 kW per ton x $1.787 per kW-month x 12 months per year
= $15,268

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	712
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$15,268
Analysis Period:	25 Years
Estimated Construction Cost:	$192,000
Simple Payback:	12.6 Years
Savings-to-Investment Ratio (SIR):	0.9

Recommendation: Do not implement.

CENTRAL PLANT 730 ECO 5.
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Premise:
This ECO evaluates the use of two-speed fans and variable-speed fans as an alternative to save energy used by the cooling tower. A cooling tower fan drive is built to supply enough air to cool the water to a specified range when the air is at the design wet-bulb (WB). When the air has a lower WB, less air volume is required to do the same job. Since cooling towers must perform even at the worst conditions, and since actual conditions are better than the worst case 98% of the time, the air flow, and therefore the horsepower, required is much less than is built into the cooling tower.

Basically, the more water (and heat) to cool, the more air required to cool it. Also, the lower the inlet air WB to the cooling tower (the lower the inlet air heat content), the less air flow required to cool the water.

In some multicell mechanical-draft cooling towers, the isolation of individual cell air streams is ineffective because of one or more of the following:

- Partitions are missing or in need of repair.
- Partitions are incomplete or the water level is too low.

This condition results in temperature control problems. When one fan of a multicell tower is off, and another cell is running at half or full speed, a substantial amount of air comes from the cells which are off. The air bypasses the wetted fill, causing the fan to operate longer, hence reducing cooling tower efficiency. This problem can be corrected by the use of variable-speed fans. At thermal conditions less than design, all fans can be operated at the precise speed required to maintain the condenser water temperature. Thus, the cooling air will flow through the fill, even without partitions, and no more power will be expended than is necessary.

Some existing cooling towers at Fort Sill presently take advantage of two-speed fan control, but none take advantage of variable-speed cooling tower control.

Basis for Analysis:
The savings for this ECO were calculated with the following basis for analysis:

- The heat released by water must equal the heat absorbed by air in order for the cooling tower to function

- An approximation is made from computer energy simulation runs of the hourly profile of building cooling loads.

(Continued)

CENTRAL PLANT 730 ECO 5. (Continued)
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Basis for Analysis: (Continued)

- Knowing the performance of the tower and the ambient wet bulb temperature, the percent of design capacity can be calculated for each part load condition and WB temperature.

- The number of stages of control for the two-speed fan retrofit was calculated based on the number of existing tower fans.

- Brake horsepower of the fan varies as the cube of the air flow. The difference in energy was calculated by taking into account the efficiency of the motor and variable-speed drive.

- The cost for two-speed control was based on new motors and controls for existing towers.

- The cost for variable-speed control was based on new variable-frequency, variable-speed drive retrofit to existing motors.

Results:

5(A), Two-Speed Fan Retrofit:

Annual Electricity Savings (kWh):	17,441
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$239
Analysis Period:	25 Years
Estimated Construction Cost:	$14,890
Simple Payback:	59 Years
Savings-to-Investment Ratio (SIR):	0.2

5(B), Variable-speed Retrofit:

Annual Electricity Savings (kWh):	18,709
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$256
Analysis Period:	25 Years
Estimated Construction Cost:	$10,180
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:

Two-Speed Fan Retrofit: Do not implement.

Variable-speed Retrofit: Do not implement.

CENTRAL PLANT 730 ECO 6.
INSTALL HIGH-EFFICIENCY MOTORS

Premise:
This ECO proposes to replace existing motors with high-efficiency motors to save electrical energy. The savings from installing high-efficiency motors are given by:

$$\text{Existing motor efficiency} = \frac{(\text{hp} * 0.746)}{(\text{FLA} * \text{Volts} * \text{PF} * \sqrt{3})}$$

kW saved = (Amps * Volts * PF * $\sqrt{3}$) * (1/existing motor eff. - 1/new motor eff.)

kWh saved per year = (kW saved * hours per year operation)

where:

hp = Nameplate horsepower of existing motor
0.746 = kW/hp
FLA = Nameplate full load amps
Amps = Measured amps of existing motor
Volts = Measured volts of existing motor
PF = Measured power factor of existing motor
$\sqrt{3}$ = Conversion for three phase power
New motor efficiency = from manufacturers' data

Basis for Analysis:
The savings for this ECO were calculated using the hours of motor operation, the existing motor efficiency, and the new motor efficiency. A spreadsheet was used to set up the appropriate formulas.

Results:

Annual Electricity Savings (kWh):	85,430
Peak Electrical Demand Savings (kW):	041
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$2,049
Analysis Period:	25 Years
Estimated Construction Cost:	$50,297
Simple Payback:	23 Years
Savings-to-Investment Ratio (SIR):	0.5

Recommendation:
Do not implement. The government should install high-efficiency motors any time the existing motors require replacement because of other reasons.

CENTRAL PLANT 730 ECO 7.
INSTRUMENTATION TO ESTABLISH BOILER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the boiler.

Boiler plant operators start and stop individual boilers based on their estimate of the daily weather. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the required heating capacity and the relevant controls allows minimizing the amount of time extra boilers are operated unnecessarily, thus lowering standby losses. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
Based on field survey observations and interviews with boiler operators, the boilers are operated at least 30 days more per year than the load requires. Running extra boilers has the effect of increasing standby losses.

The energy saved by this ECO is the energy lost by the boiler in standby for 30 days per year.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	89
Total Annual Utility Cost Savings:	$260
Analysis Period:	15 Years
Estimated Construction Cost:	$4,482
Simple Payback:	966 Years
Savings-to-Investment Ratio (SIR):	0.21

Recommendation: Do not implement.

CENTRAL PLANT 730 ECO 8.
OPTIMIZE BOILER OPERATION

Premise:
This ECO proposes to optimize boiler operation by maximizing use of higher efficiency boilers. The three boilers in use have system efficiencies ranging from 81.4% to 81.7%. Because all three boilers operate near optimal efficiency and are sized equally, there is no benefit in resequencing boiler operation. This ECO is thus not applicable to Central Plant 730.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 730 EC0 9.
IMPROVE BOILER EFFICIENCY

Premise:
This ECO proposes to improve boiler efficiency by renovating boilers, associated equipment, and controls to reduce energy use. Based on combustion efficiency testing and field survey observations, the system efficiencies of the boilers range from 81.4% to 81.7%. Because the boilers operate near optimal system efficiency, little can be done to increase boiler efficiency. However, boiler 1 should be renovated to correct a problem with soot. Because the boiler plant has excess capacity, the operating hours of boiler 1 are minimal. Therefore, the energy savings do not justify the cost of renovation.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 730 ECO 10.
INSTALL COMBUSTION CONTROLS

Premise:
This ECO proposes to install combustion controls to optimize the fuel-to-air ratio, increasing combustion efficiency and saving energy.

Based on combustion efficiency tests conducted during field surveys, boilers had excessive O_2 in the flue gas. This excessive O_2 transports more heat than necessary out of the boiler, decreasing efficiency and therefore the maximum useful output of a boiler.

Regular testing, by manual or automatic means, enables boiler operators to adjust the fuel-to-air ratio, thereby increasing boiler efficiency.

Depending on the level of energy savings, costs are estimated for manual or automatic testing equipment and controls.

Basis of Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Boiler efficiency inputs were adjusted to increase the maximum useful output of the boilers for a given fuel input. The energy savings of this ECO is the difference between the baseline and the ECO energy simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	108
Total Annual Utility Cost Savings:	$315
Analysis Period:	15 Years
Estimated Construction Cost:	$29,654
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 730 ECO 11.
INSTALL HIGH EFFICIENCY BURNERS

Premise:
All burners require excess air to ensure complete fuel combustion. The excess air represents a loss because the boiler uses energy to heat it, and it is emitted hot with the flue gas. Low excess air burners meeting environmental criteria minimize this type of loss. Combustion air requirements for low excess air burners vary with the firing rates; for low firing rates, excess air must be increased. The percentage of increase varies substantially with the burner manufacturer. A burner that has relatively flat excess air requirements at low firing rates will reduce energy requirements.

Basis for Analysis:
EMC contacted representatives of numerous burner manufacturers; however, it was not possible to locate a burner with a capacity small enough to match these boilers. This ECO is thus not applicable for this central plant.

Results: N/A

Recommendation: N/A

CENTRAL PLANT 730 ECO 12.
INSTALL STACK ECONOMIZER OR AIR PREHEATER

Premise:
This ECO proposes to install stack economizers or air preheaters to recover heat from the boiler stack and thereby save energy. Many of the boiler stack temperatures are high enough to allow significant heat loss.

Based on professional engineering judgement, field survey observations, and published boiler data, economizers are not applicable to any of the boilers in Building 730 because inadequate boiler heat transfer surface is not indicated, nor do high stack temperatures exist. In addition, boiler room space is inadequate to install equipment. This ECO is thus not applicable to Central Plant 730.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 730 ECO 14.
NEW PUMPS TO MATCH FLOW REQUIREMENTS

Premise:
The main chilled water pumps in Building 730 were designed to handle a load of 800 tons of cooling each. This is a properly sized load for the existing 800 ton chiller; however, with 300 tons of cooling load or less, running the excess flow is not required, and a smaller pump is needed. This ECO evaluated the installation of a smaller pump to handle the 300 ton chiller.

Basis for Analysis:
The energy savings from installing a smaller pump to handle the cooling load of the 300 ton chiller was determined. The flow was based on the tonnage and design TD for the 300 ton chiller. The required pressure drop for the smaller pump was assumed to be the same as the pressure drop for the existing main chilled water pumps. The horsepower was calculated for a smaller pump to meet the new flow requirements. The difference between the existing main chilled water pump kW and the proposed smaller pump kW was calculated based on an assumed pump and motor efficiency. The hours of operation for the smaller pump were taken from the PC-CUBE energy simulation base load computer run. Hours of operation were any hours when the cooling load on the chiller plant was 300 tons or less. The kW motor savings times the hours of operation were the potential kWh savings for this ECO.

Results:

Annual Electricity Savings (kWh):	144,560
Peak Electrical Demand Savings (kW):	
Annual Natural Gas Savings (MMBtu):	
Total Annual Utility Cost Savings:	$1,980
Analysis Period:	25 Years
Estimated Construction Cost:	$12,809
Simple Payback:	6.1 Years
Savings-to-Investment Ratio (SIR):	1.8

Recommendation: Implement.

CENTRAL PLANT 730 ECO 17.
ELECTRIC BOILERS FOR SUMMER DHW

Premise:
This ECO analyzes separate electric boilers to provide DHW in individual buildings during the summer. This measure will allow the central heating plant to shut down during the summer and will save distribution losses and pumping energy.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. All boiler input data were changed to simulate electric HW generators to determine the economic feasibility of summer DHW heaters. Cost estimates were prepared for electric boilers for each individual building.

Results:

Annual Electricity Savings (kWh):	-48,800
Peak Electrical Demand Savings (kW):	-121
Annual Natural Gas Savings (MMBtu):	1,582
Total Annual Utility Cost Savings:	$1,356
Analysis Period:	25 Years
Estimated Construction Cost:	$38,431
Simple Payback:	27 Years
Savings-to-Investment Ratio (SIR):	1.2

Recommendation: Implement.

4.3 CENTRAL PLANT 914 EVALUATION

4.3.1 Baseline Energy Usage

Using the PC-CUBE program, Central Plant 914 was evaluated to determine the baseline energy usage as the plant is currently operated. The baseline calculation considered heating and cooling loads, DHW loads, and central plant efficiencies.

The central plant operating procedures taken into account for the baseline calculation included:

- Chiller 1 (400 tons) is operated in the summer months.
- Boilers 1, 2, and 3 are operated in the winter months for heating.
- Boiler 4 is operated year-round to serve the DHW loads.

The study results indicate the 400 ton chiller would operate at a range of loads, with a significant number of hours at 31% to 40% loading. The boiler loads indicate a peak loading for two boilers in the winter, with the third boiler requiring a maximum of only 40% loading. The majority of operating hours for boiler 4 in the summer are at 11% to 20% loading.

The estimated annual baseline energy consumption and demand for the chiller in Central Plant 914 are:

- Total electrical consumption, 563,059 kWh
- Peak electrical demand, 286 kW.

The estimated annual baseline energy consumption for boilers in Central Plant 914 is:

- Total natural gas consumption, 13,855 MMBtu.

4.3.2 ECO Evaluation

CENTRAL PLANT 914 ECO 1.
INSTALL INSTRUMENTATION TO ESTABLISH CHILLER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the chiller plant.

Chiller plant operators start and stop individual chillers based on their estimate of the daily weather and the chilled water return temperature. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the actual cooling load minimizes the amount of time extra chillers are operated unnecessarily. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Because extra chillers are not operated unnecessarily in Central Plant 914, this ECO is not applicable.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 914 ECO 2.
OPTIMIZE CHILLER OPERATION

Premise:
This ECO proposes to optimize chiller sequence of operation.

Because only one chiller is used to meet cooling loads, this ECO is not applicable to Central Plant 914.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 914 ECO 3.
INCREASE CHILLER EFFICIENCY

Premise:
This ECO proposes to repair the chiller to obtain a higher efficiency.

The chiller operates with an efficiency of 1.07 kW per ton. Design characteristics of the chiller indicate possible performance of 0.60 kW per ton at new condition. Performing minor repairs, cleaning, and other system modifications as necessary will increase the efficiency of the chiller.

Basis for Analysis:
The PC-CUBE energy simulation program is used to analyze this ECO. Chiller performance data, representing a 38% improvement in efficiency, was entered in place of the tested performance data. The energy saved by this ECO was the difference between the baseline and the ECO simulations.

The cost was based on a one time minor repair project and an annual maintenance contract to maintain chiller operation at peak efficiency.

Results:

Annual Electricity Savings (kWh):	130,000
Peak Electrical Demand Savings (kW):	93
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$3,775
Analysis Period:	15 Years
Estimated Construction Cost:	$3,165
Simple Payback:	3.88 Years
Savings-to-Investment Ratio (SIR):	2.15

Recommendation: Implement.

CENTRAL PLANT 914 ECO 4.
INSTALL ICE STORAGE COOLING SYSTEM

Premise:
This ECO proposes to install an ice storage cooling system to reduce peak air conditioning electrical demand (load shifting) and cost.

The primary advantage of an ice storage cooling system is the ability to use lower time-of-day electricity rates and off-peak demand rates to produce ice which can be used instead of chillers to provide cooling for HVAC equipment during times of peak electrical use. Fort Sill does not have this type of rate structure; however, if the overall peak electrical demand can be reduced by shutting off chillers during peak periods, demand charges can be reduced for the whole year.

Basis for Analysis:
The savings of this ECO are calculated, based on the following assumptions.

- A reduction in chiller use of four hours per day is sufficient to reduce peak electrical demand.
- The reduction in demand will occur simultaneously with the overall base peak electrical demand.
- The auxiliary electrical loads imposed by the ice storage system exactly offset the reduction in chiller auxiliary electrical use.
- The performance penalty due to the chillers producing ice instead of water at normal chilled water temperatures was not taken into consideration (best case scenario).
- The electrical demand savings are $1.787 per kW.

Cost and savings calculations are shown below:

Cost
= Tons capacity x hours per day x $60 per ton-hour
= 400 Tons x 4 hours per day x $60 per ton-hour
= $96,000

(Continued)

CENTRAL PLANT 914 ECO 4. (Continued)
INSTALL ICE STORAGE SYSTEM

Annual Savings
= Tons capacity x kW per ton x $1.787 per kW-month x 12 months per year
= 400 Tons x 1.07 kW per ton x $1.787 per kW-month x 12 months per year
= $9,178

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	428
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$9,178
Analysis Period:	25 Years
Estimated Construction Cost:	$96,000
Simple Payback:	10.5 Years
Savings-to-Investment Ratio (SIR):	1.1

Recommendation: Implement.

CENTRAL PLANT 914 ECO 5.
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Premise:
This ECO evaluates the use of two-speed fans and variable-speed fans as an alternative to save energy used by the cooling tower. A cooling tower fan drive is built to supply enough air to cool the water to a specified range, when the air is at the design WB. When the air has a lower WB, less air volume is required to do the same job. Since cooling towers must perform even at the worst conditions, and since actual conditions are better than the worst case 98% of the time, the air flow, and therefore the horsepower, required is much less than is built into the cooling tower.

Basically, the more water (and heat) to cool, the more air required to cool it. Also, the lower the inlet air WB to the cooling tower (the lower the inlet air heat content), the less air flow required to cool the water.

In some multicell mechanical-draft cooling towers, the isolation of individual cell air streams is ineffective because of one or more of the following:

- Partitions are missing or in need of repair.
- Partitions are incomplete or the water level is too low.

This condition results in temperature control problems. When one fan of a multicell tower is off, and another cell is running at half or full speed, a substantial amount of air comes from the cells which are off. The air bypasses the wetted fill, causing the fan to operate longer, hence reducing cooling tower efficiency. This problem can be corrected by the use of variable-speed fans. At thermal conditions less than design, all fans can be operated at the precise speed required to maintain the condenser water temperature. Thus, the cooling air will flow through the fill, even without partitions, and no more power will be expended than is necessary.

Some existing cooling towers at Fort Sill presently take advantage of two-speed fan control, but none take advantage of variable-speed cooling tower control.

Basis for Analysis:
The savings for this ECO were calculated with the following basis for analysis:

- The heat released by water must equal the heat absorbed by air in order for the cooling tower to function.

- An approximation is made from computer energy simulation runs of the hourly profile of building cooling loads.

(Continued)

CENTRAL PLANT 914 ECO 5. (Continued)
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Basis for Analysis: (Continued)

- Brake horsepower of the fan varies as the cube of the air flow. The difference in energy was calculated by taking into account the efficiency of the motor and variable-speed drive.

- Knowing the performance of the tower and the ambient wet bulb temperature, the percent of design capacity can be calculated for each part load condition and WB temperature.

- The cost for variable-speed control was based on new variable-frequency, variable-speed drive retrofit to existing motors.

- The cooling tower for Central Plant 914 already has a two-speed control.

Results:
5(A), Two-Speed Fan Retrofit: N/A

5(B), Variable-Speed Retrofit:

Annual Electrical Savings (kWh):	2,697
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$37
Analysis Period:	25 Years
Estimated Construction Cost:	$6,352
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:
Two-Speed Fan Retrofit: N/A

Variable-Speed Retrofit: Do not implement.

CENTRAL PLANT 914 ECO 6.
INSTALL HIGH-EFFICIENCY MOTORS

Premise:
This ECO proposes to replace existing motors with high-efficiency motors to save electrical energy. The savings from installing high-efficiency motors are given by:

$$\text{Existing motor efficiency} = \frac{(hp * 0.746)}{(FLA * Volts * PF * \sqrt{3})}$$

kW saved = (Amps * Volts * PF * $\sqrt{3}$) * (1/existing motor eff. - 1/new motor eff.)

kWh saved per year = (kW saved * hours per year operation)

where:

hp = Nameplate horsepower of existing motor
0.746 = kW/hp
FLA = Nameplate full load amps
Amps = Measured amps of existing motor
Volts = Measured volts of existing motor
PF = Measured power factor of existing motor
$\sqrt{3}$ = Conversion for three phase power
New motor efficiency = from manufacturers' data

Basis for Analysis:
The savings for this ECO were calculated using the hours of motor operation, the existing motor efficiency, and the new motor efficiency. A spreadsheet was used to set up the appropriate formulas.

Results:

Annual Electricity Savings (kWh):	8,932
Peak Electrical Demand Savings (kW):	5
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$229
Analysis Period:	25 Years
Estimated Construction Cost:	$9,429
Simple Payback:	39 Years
Savings-to-Investment Ratio (SIR):	0.29

Recommendation:
Do not implement. The government should install high-efficiency motors any time the existing motors require replacement for other reasons.

CENTRAL PLANT 914 ECO 7.
INSTRUMENTATION TO ESTABLISH BOILER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the boiler.

Boiler plant operators start and stop individual boilers based on their estimate of the daily weather. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the required heating capacity and the relevant controls allows minimizing the amount of time extra boilers are operated unnecessarily, thus lowering standby losses. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
Based on field survey observations and interviews with boiler operators, the boilers are operated at least 30 days more per year than the load requires. Running extra boilers has the effect of increasing standby losses.

The energy saved by this ECO is the energy lost by the boiler in standby for 30 days per year.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	11
Total Annual Utility Cost Savings:	$32
Analysis Period:	15 Years
Estimated Construction Cost:	$5,620
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 914 ECO 8.
OPTIMIZE BOILER OPERATION

Premise:
This ECO proposes to optimize boiler operation by maximizing use of higher efficiency boilers. The three boilers in use have system efficiencies ranging from 74% to 78%. The boilers with the lowest efficiencies operate a majority of the heating season hours, while higher efficiency boilers remain idle. Resequencing the higher efficiency boilers to operate more hours will save energy.

Basis for Analysis:
The PC-CUBE energy simulation is used to analyze this ECO. The boiler sequence is changed from the baseline sequence to operate boilers from the most efficient first, to the least efficient last. The energy saved by this ECO is the difference between the baseline and the ECO computer simulation.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	44
Total Annual Utility Cost Savings:	$128
Analysis Period:	15 Years
Estimated Construction Cost:	$33,847
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Results: N/A

Recommendation: Do not implement.

CENTRAL PLANT 914 ECO 9.
IMPROVE BOILER EFFICIENCY

Premise:
This ECO proposes to improve boiler efficiency by renovating boilers, associated equipment, and controls to reduce energy use. Based on combustion efficiency testing and field survey observations, the system efficiencies of the primary boilers range from 74% to 78%. Renovating the boilers and associated controls will increase system efficiencies and save energy.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. As losses from the boilers are reduced, the maximum output of the boiler increases. Because the boilers cannot be renovated to 100% of the design capacity, maximum boiler outputs were increased to within 1% to 2% of the maximum outputs based on rated input to the boilers.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	500
Total Annual Utility Cost Savings:	$1,460
Analysis Period:	25 Years
Estimated Construction Cost:	$18,035
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 914 ECO 10.
INSTALL COMBUSTION CONTROLS

Premise:
This ECO proposes to install combustion controls to optimize the fuel-to-air ratio, increasing combustion efficiency and saving energy.

Based on combustion efficiency tests conducted during field surveys, boilers had excessive O_2 in the flue gas. This excessive O_2 transports more heat than necessary out of the boiler, decreasing efficiency and the maximum useful output of a boiler.

Because the boilers do not have a burner which can be modulated by automatic means to change the fuel-to-air ratio based on O_2 and temperature measurements, this ECO was not applicable.

Basis of Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 914 ECO 11.
INSTALL HIGH EFFICIENCY BURNERS

Premise:
All burners require excess air to ensure complete fuel combustion. The excess air represents a loss because the boiler uses energy to heat it, and it is emitted hot with the flue gas. Low excess air burners meeting environmental criteria minimize this type of loss. Combustion air requirements for low excess air burners vary with the firing rates; for low firing rates, excess air must be increased. The percentage of increase varies substantially with the burner manufacturer. A burner that has relatively flat excess air requirements at low firing rates will reduce energy requirements.

Basis for Analysis:
EMC contacted representatives of numerous burner manufacturers; however, it was not possible to locate a burner with a capacity small enough to match the boilers. This ECO is not applicable for this central plant.

Results: N/A

Recommendation: N/A

CENTRAL PLANT 914 ECO 12.
INSTALL STACK ECONOMIZER OR AIR PREHEATER

Premise:
This ECO proposes to install stack economizers or air preheaters to recover heat from the boiler stack and thereby save energy. Many of the boiler stack temperatures are high enough to allow significant heat loss.

Based on professional engineering judgement, field survey observations, and published boiler data, economizers are not applicable to any of the boilers in Building 914 because inadequate boiler heat transfer surface is not indicated, nor do high stack temperatures exist. In addition, boiler room space is inadequate to install equipment. This ECO is thus not applicable to Central Plant 914.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

4.4 CENTRAL PLANT 2812 EVALUATION

4.4.1 Baseline Energy Usage

Using the PC-CUBE program, Central Plant 2812 was evaluated to determine the baseline energy usage as the plant is currently operated. The baseline calculation considered heating and cooling loads, DHW loads, distribution losses, and central plant efficiencies.

The central plant operating procedures taken into account for the baseline calculation include:

- Chiller 1 (372 tons) is operated in the summer months.
- Boiler 1 is operated year-round to serve heating and DHW loads.
- Boiler 2 is operated in the winter to serve heating and DHW loads.
- Boiler 3 is operated year round for DHW loads in the mess hall.
- HW distribution pumps operate year-round to circulate water to buildings served.

The results of the study indicate the 372 ton chiller operates a significant number of hours at 21% to 30% loading. The boiler loads indicate a peak loading for boiler 1 in the winter; for the second boiler, loads are spread evenly over the entire range. Boiler 1 operates the majority of the time in the 21% to 30% load range during the summer. The majority of operating hours for boiler 3 are at 11% to 20% loading.

The estimated annual baseline energy consumption and demand for chillers in Central Plant 2812 are:

- Total electrical consumption, 425,428 kWh
- Peak electrical demand, 192 kW.

The estimated annual baseline energy consumption for boilers in Central Plant 2812 is:

- Total natural gas consumption, 28,206 MMBtu
- Total electrical consumption, 92,880 kWh.

4.4.2 ECO Evaluation

CENTRAL PLANT 2812 ECO 1.
INSTALL INSTRUMENTATION TO ESTABLISH CHILLER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the chiller plant.

Chiller plant operators start and stop individual chillers based on their estimate of the daily weather and the chilled water return temperature. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the actual cooling load minimizes the amount of time extra chillers are operated unnecessarily. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Because extra chillers are not operated unnecessarily in Central Plant 2812, this ECO is not applicable.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 2812 ECO 2.
OPTIMIZE CHILLER OPERATION

Premise:
This ECO proposes to optimize chiller sequence of operation.

Because only one chiller is used to meet cooling loads, this ECO is not applicable to Central Plant 2812.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 2812 ECO 3.
INCREASE CHILLER EFFICIENCY

Premise:
This ECO proposes to replace the existing chiller to obtain a higher efficiency.

The chiller operates with an efficiency of 0.81 kW per ton. Design characteristics of a new high efficiency chiller indicate possible performance of 0.60 kW per ton at new condition. Performing minor repairs, cleaning, and other system modifications as necessary will keep the efficiency of the new chiller at its optimum.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Chiller performance data, representing a 0.21 kW per ton improvement in efficiency, is entered in place of the tested performance data. The energy saved by this ECO is the difference between the baseline and the ECO simulations.

The cost was based on a chiller replacement project and an annual maintenance contract to maintain chiller operation at peak efficiency.

Results:

Annual Electricity Savings (kWh):	72,000
Peak Electrical Demand Savings (kW):	42
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$986
Analysis Period:	25 Years
Estimated Construction Cost:	$94,894
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 2812 ECO 4.
INSTALL ICE STORAGE COOLING SYSTEM

Premise:
This ECO proposes to install an ice storage cooling system to reduce peak air conditioning electrical demand (load shifting) and cost.

The primary advantage of an ice storage cooling system is the ability to use lower time-of-day electricity rates and off-peak demand rates to produce ice which can be used instead of chillers to provide chilled water for HVAC equipment during times of peak electrical use. Fort Sill does not have this type of rate structure; however, if the overall peak electrical demand can be reduced by shutting off chillers during peak periods, demand charges can be reduced for the whole year.

Basis for Analysis:
The savings of this ECO were calculated, based on the following assumptions.

- A reduction in chiller use of four hours per day is sufficient to reduce peak electrical demand.
- The reduction in demand will occur simultaneously with the overall base peak electrical demand.
- The auxiliary electrical loads imposed by the ice storage system offset the reduction in chiller auxiliary electrical use.
- The performance penalty due to the chillers producing ice instead of water at normal chilled water temperatures was not taken into consideration (best case scenario).
- The electrical demand savings are $1.787 per kW.

Cost and savings calculations are shown below:

Cost
= Tons capacity x hours per day x $60 per ton-hour
= 372 tons x 4 hours per day x $60 per ton-hour
= $89,280

(Continued)

CENTRAL PLANT 2812 ECO 4. (Continued)
INSTALL ICE STORAGE SYSTEM

Annual Savings
= Tons capacity x kW per ton x $1.787 per kW-month x 12 months per year
= 372 Tons x 0.81 kW per ton x $1.787 per kW-month x 12 months per year
= $6,462

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	301
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$6,455
Analysis Period:	25 Years
Estimated Construction Cost:	$89,280
Simple Payback:	13.8 Years
Savings-to-Investment Ratio (SIR):	0.84

Recommendation: Do not implement.

CENTRAL PLANT 2812 ECO 5.
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Premise:
This ECO evaluates the use of two-speed fans and variable-speed fans as an alternative to save energy used by the cooling tower. A cooling tower fan drive is built to supply enough air to cool the water to a specified range, when the air is at the design WB. When the air has a lower WB, less air volume is required to do the same job. Since cooling towers must perform even at the worst conditions, and since actual conditions are better than the worst case 98% of the time, the air flow, and therefore the horsepower, required is much less than is built into the cooling tower.

Basically, the more water (and heat) to cool, the more air required to cool it. Also, the lower the inlet air WB to the cooling tower (the lower the inlet air heat content), the less air flow required to cool the water.

In some multicell mechanical-draft cooling towers, the isolation of individual cell air streams is ineffective because of one or more of the following:

- Partitions are missing or in need of repair.
- Partitions are incomplete or the water level is too low.

This condition results in temperature control problems. When one fan of a multicell tower is off, and another cell is running at half or full speed, a substantial amount of air comes from the cells which are off. The air bypasses the wetted fill, causing the fan to operate longer, hence reducing cooling tower efficiency. This problem can be corrected by the use of variable-speed fans. At thermal conditions less than design, all fans can be operated at the precise speed required to maintain the condenser water temperature. Thus, the cooling air will flow through the fill, even without partitions, and no more power will be expended than is necessary.

Some existing cooling towers at Fort Sill presently take advantage of two-speed fan control, but none take advantage of variable-speed cooling tower control.

Basis for Analysis:
The savings for this ECO were calculated with the following basis for analysis:

- The heat released by water must equal the heat absorbed by air in order for the cooling tower to function.

- An approximation is made from computer energy simulation runs of the hourly profile of building cooling loads.

(Continued)

CENTRAL PLANT 2812 ECO 5. (Continued)
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Basis for Analysis: (Continued)

- Knowing the performance of the tower and the ambient wet bulb temperature, the percent of design capacity can be calculated for each part load condition and WB temperature.

- The number of stages of control for the two-speed fan retrofit is calculated based on the number of existing tower fans.

- Brake horsepower of the fan varies as the cube of the air flow. The difference in energy was calculated by taking into account the efficiency of the motor and variable-speed drive.

- The cost for two-speed control was based on new motors and controls for existing towers.

- The cost for variable-speed control was based on new variable-frequency, variable-speed drive retrofit to existing motors.

Results:

5(A), Two-Speed Fan Retrofit:

Annual Electricity Savings (kWh):	8,560
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$117
Analysis Period:	25 Years
Estimated Construction Cost:	$7,077
Simple Payback:	57 Years
Savings-to-Investment Ratio (SIR):	0.2

5(B), Variable-speed Retrofit:

Annual Electricity Savings (kWh):	11,167
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$153
Analysis Period:	25 Years
Estimated Construction Cost:	$5,236
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:

Two-speed fan control: Do not implement.

Variable-speed fan control: Do not implement.

CENTRAL PLANT 2812 ECO 6.
INSTALL HIGH-EFFICIENCY MOTORS

Premise:
This ECO proposes to replace existing motors with high-efficiency motors to save electrical energy. The savings from installing high-efficiency motors are given by:

$$\text{Existing motor efficiency} = \frac{(hp * 0.746)}{(FLA * Volts * PF * \sqrt{3})}$$

kW saved = (Amps * Volts * PF * √3) * (1/existing motor eff. - 1/new motor eff.)

kWh saved per year = (kW saved * hours per year operation)

where:

hp = Nameplate horsepower of existing motor
0.746 = kW/hp
FLA = Nameplate full load amps
Amps = Measured amps of existing motor
Volts = Measured volts of existing motor
PF = Measured power factor of existing motor
√3 = Conversion for three phase power
New motor efficiency = from manufacturers' data

Basis for Analysis:
The savings for this ECO were calculated using the hours of motor operation, the existing motor efficiency, and the new motor efficiency. A spreadsheet was used to set up the appropriate formulas.

Results:

Annual Electricity Savings (kWh):	18,353
Peak Electrical Demand Savings (kW):	4
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$337
Analysis Period:	25 Years
Estimated Construction Cost:	$8,368
Simple Payback:	24 Years
Savings-to-Investment Ratio (SIR):	0.5

Recommendation:
Do not implement. The government should install high-efficiency motors any time the existing motors require replacement for other reasons.

CENTRAL PLANT 2812 ECO 7.
INSTRUMENTATION TO ESTABLISH BOILER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the boiler.

Boiler plant operators start and stop individual boilers based on their estimate of the daily weather and the HTHW return temperature. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the required heating capacity and the relevant controls allows minimizing the amount of time extra boilers are operated unnecessarily, thus lowering standby losses. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
Based on field survey observations and interviews with boiler operators, the boilers are operated at least 30 days more per year than the load requires. Running extra boilers has the effect of increasing standby losses.

The energy saved by this ECO is the energy lost by the boiler in standby for 30 days per year.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	21
Total Annual Utility Cost Savings:	$61
Analysis Period:	15 Years
Estimated Construction Cost:	$5,620
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 2812 ECO 8.
OPTIMIZE BOILER OPERATION

Premise:
This ECO proposes to optimize boiler operation by maximizing use of higher efficiency boilers. The boilers in use operate with system efficiencies ranging from 71.5% to 79.7%. The boilers with the lowest efficiencies operate a majority of the heating season hours, while higher efficiency boilers remain idle. Resequencing the higher efficiency boilers to operate more hours will save energy.

Basis for Analysis:
The PC-CUBE energy simulation is used to analyze this ECO. The boiler sequence is changed from the baseline sequence to operate boilers from the most efficient first, to the least efficient last. The energy saved by this ECO is the difference between the baseline and ECO computer simulation.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	307
Total Annual Utility Cost Savings:	$896
Analysis Period:	15 Years
Estimated Construction Cost:	$27,128
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 2812 EC0 9.
IMPROVE BOILER EFFICIENCY

Premise:
This ECO proposes to improve boiler efficiency by renovating boilers, associated equipment, and controls to reduce energy use. Based on combustion efficiency testing and field survey observations, the system efficiencies of the boilers range from 71% to 81%. Overhauling the two worst boilers, which have efficiencies of 71% and 74%, and the associated controls, will increase system efficiencies and save energy.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. As losses from the boilers are reduced, the maximum output of the boiler increases. Because the boilers cannot be renovated to 100% of the design capacity, maximum boiler outputs were increased to within 1% to 2% of the maximum outputs based on rated input to the boilers.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	621
Total Annual Utility Cost Savings:	$1,813
Analysis Period:	15 Years
Estimated Construction Cost:	$6,012
Simple Payback:	8 Years
Savings-to-Investment Ratio (SIR):	2.2

Recommendations: Implement

CENTRAL PLANT 2812 ECO 10.
INSTALL COMBUSTION CONTROLS

Premise:
This ECO proposes to install combustion controls to optimize the fuel-to-air ratio, increasing combustion efficiency and saving energy.

Based on combustion efficiency tests conducted during field surveys, boilers had excessive O_2 in the flue gas. This excessive O_2 transports more heat than necessary out of the boiler, decreasing efficiency and therefore the maximum useful output of a boiler.

Because the boilers do not have a burner which can be modulated by automatic mens to change the fuel-to-air ratio based on O_2 and temperature measurements, this ECO was not applicable.

Basis of Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 2812 ECO 11.
INSTALL HIGH EFFICIENCY BURNERS

Premise:
All burners require excess air to ensure complete fuel combustion. The excess air represents a loss because the boiler uses energy to heat it and it is emitted hot with the flue gas. Low excess air burners meeting environmental criteria minimize this type of loss. Combustion air requirements for low excess air burners vary with the firing rates; for low firing rates, excess air must be increased. The percentage of increase varies substantially with the burner manufacturer. A burner that has relatively flat excess air requirements at low firing rates will reduce energy requirements.

Basis for Analysis:
EMC contacted representatives of numerous burner manufacturers; however, it was not possible to locate a burner with a capacity small enough to match these boilers. This ECO is thus not applicable for this central plant.

Results: N/A

Recommendation: N/A

CENTRAL PLANT 2812 ECO 12.
INSTALL STACK ECONOMIZER OR AIR PREHEATER

Premise:
This ECO proposes to install stack economizers or air preheaters to recover heat from the boiler stack and thereby save energy. Many of the boiler stack temperatures are high enough to allow significant heat loss.

Based on professional engineering judgement, field survey observations, and published boiler data, economizers are not applicable to any of the boilers in Building 2812 because inadequate boiler heat transfer surface is not indicated, nor do high stack temperatures exist. In addition, boiler room space is inadequate to install equipment. This ECO is thus not applicable to Central Plant 2812.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 2812 ECO 16.
NATURAL GAS DRIVEN CHILLER

Premise:
An investigation was conducted at Central Plant 6003 to determine if natural gas driven chillers would be economically feasible. Reclaimed heat from the engines would be used to produce hot water for the summer heating loads, including DHW and distribution losses.

Central Plant 2812 was selected for the natural gas driven chiller analysis because of a number of factors:

- Summer chiller electrical loads
- Summer heating loads
- Sufficient area to expand plant for additional equipment.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The performance curve for a natural gas driven chiller was input to handle 100% of the cooling load for Central Plant 2812. The recoverable heat from the natural gas driven chiller was used to meet the heating load of the central plant. The energy saved by this ECO is the difference between the baseline and ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	278,000
Peak Electrical Demand Savings (kW):	144
Annual Natural Gas Savings (MMBtu):	-1498
Total Annual Utility Cost Savings:	$2,522
Analysis Period:	25 Years
Estimated Construction Cost:	$444,584
Simple Payback:	185 Years
Savings-to-Investment Ratio (SIR):	0

The cost of electrical energy and demand from the utility are too low in this case to offset the inefficiencies of natural gas driven chillers. The heating load in this case was not large enough to utilize the amount of waste heat generated.

Recommendation: Do not implement.

CENTRAL PLANT 2812 ECO 17.
ELECTRIC BOILERS FOR SUMMER DHW

Premise:
This ECO analyzes separate electric boilers to provide DHW in individual buildings during the summer. This measure will allow the central heating plant to shut down during the summer and will save distribution losses and pumping energy.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO.

All boiler input data were changed to simulate electric HW generators to determine the economic feasibility of summer DHW heaters. Cost estimates were prepared for electric boilers for each individual building.

Results:

Annual Electricity Savings (kWh):	-726,000
Peak Electrical Demand Savings (kW):	-176
Annual Natural Gas Savings (MMBtu):	7,346
Total Annual Utility Cost Savings:	$7,794
Analysis Period:	25 Years
Estimated Construction Cost:	$7,730
Simple Payback:	22.3 Years
Savings-to-Investment Ratio (SIR):	1.3

Recommendation: Implement.

4.5 CENTRAL PLANT 3442 EVALUATION

4.5.1 Baseline Energy Usage

Using the PC-CUBE program, Central Plant 3442 was evaluated to determine the baseline energy usage as the central plant is currently operated. The baseline calculation considered central plant cooling loads and efficiencies.

The central plant operating procedures taken into account for the baseline calculation include:

- Chillers 1 and 2 (600 tons each) are operated continuously in the summer months.

It was assumed both chillers are run manually, instead of through the Trane TRACE automation system.

The results of the study indicate each chiller would operate a significant number of hours at 21% to 30% loading, with a maximum load of 80%.

The estimated annual baseline energy consumption and demand for chillers in Central Plant 3442 are:

- Total electrical consumption, 1,340,162 kWh
- Peak electrical demand, 590 kW.

4.5.2 ECO Evaluation

CENTRAL PLANT 3442 ECO 1.
INSTALL INSTRUMENTATION TO ESTABLISH CHILLER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the chiller plant.

Chiller plant operators start and stop individual chillers based on their estimate of the daily weather and the chilled water return temperature. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the actual cooling load minimizes the amount of time extra chillers are operated unnecessarily. The energy savings result from:

- The difference in operating efficiency of the chillers operating at lower load than would be the case if they were more fully loaded.
- The difference in operating only the pumps and cooling towers required for the number of chillers to meet the load.

Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The chiller sequence of operation was changed from the sequence used in the baseline to a sequence in which chiller 1 is on until its rated capacity is reached, then chiller 2 is started and picks up the load in excess of the rated capacity of the first chiller.

The energy saved by this ECO is the difference between the baseline and ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	209,000
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$2,863
Analysis Period:	15 Years
Estimated Construction Cost:	$4,012
Simple Payback:	1.4 Years
Savings-to-Investment Ratio (SIR):	6.0

Recommendation: Implement.

CENTRAL PLANT 3442 ECO 2.
OPTIMIZE CHILLER OPERATION

Premise:
This ECO proposes to optimize chiller sequence of operation. Two chillers with different efficiencies operate to meet the chilled water load. Currently, the less efficient chiller operates more hours than the chiller with the higher efficiency. During the times when both chillers are not required, energy can be saved by operating the more efficient chiller.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The Chiller Identification Numbers were resequenced to simulate starting chillers in a different order.

The energy saved by this ECO is the difference between the baseline and the ECO simulations.

Results:

Annual Electricity Savings (kWh):	281,000
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$3,850
Analysis Period:	15 Years
Estimated Construction Cost:	$16,499
Simple Payback:	5.4 Years
Savings-to-Investment Ratio (SIR):	1.6

Recommendation: Implement.

CENTRAL PLANT 3442 ECO 3.
INCREASE CHILLER EFFICIENCY

Premise:
This ECO proposes to repair the chiller to obtain a higher efficiency.

The two chillers operate with efficiencies ranging from 0.62 kW per ton to 0.68 kW per ton. Because these chillers are operating with good efficiencies, this ECO is not applicable to Central Plant 3442.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 3442 ECO 4.
INSTALL ICE STORAGE COOLING SYSTEM

Premise:
This ECO proposes to install an ice storage cooling system to reduce peak air conditioning electrical demand (load shifting) and cost.

The primary advantage of an ice storage cooling system is the ability to use lower time-of-day electricity rates and off-peak demand rates to produce ice which can be used instead of chillers to provide cooling for HVAC equipment during times of peak electrical use. Fort Sill does not have this type of rate structure; however, if the overall peak electrical demand can be reduced by shutting off chillers during peak periods, demand charges can be reduced for the whole year.

Basis for Analysis:
The savings of this ECO were calculated, based on the following assumptions.

- A reduction in chiller use of four hours per day is sufficient to reduce peak electrical demand.
- The reduction in demand will occur simultaneously with the overall base peak electrical demand.
- The auxiliary electrical loads imposed by the ice storage system offset the reduction in chiller auxiliary electrical use.
- The performance penalty due to the chillers producing ice instead of water at normal chilled water temperatures was not taken into consideration (best case scenario).
- The electrical demand savings are $1.787 per kW.

Cost and savings calculations are shown below:

Cost
= Tons capacity x hours per day x $60 per ton-hour
= 1,200 Tons x 4 hours per day x $60 per ton-hour
= $288,000

(continued)

CENTRAL PLANT 3442 ECO 4. (Continued)
INSTALL ICE STORAGE SYSTEM

Annual Savings
= Tons capacity kW per ton x \$1.787 per kW-month x 12 months per year
= 1,200 Tons x 0.65 kW per ton x \$1.787 per kW-month x 12 months per year
= \$16,726

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	780
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	\$16,726
Analysis Period:	25 Years
Estimated Construction Cost:	\$288,000
Simple Payback:	17.2 Years
Savings-to-Investment Ratio (SIR):	0.7

Recommendation: Do not implement.

CENTRAL PLANT 3442 ECO 5.
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Premise:
This ECO evaluates the use of two-speed fans and variable-speed fans as an alternative to save energy used by the cooling tower. A cooling tower fan drive is built to supply enough air to cool the water to a specified range, when the air is at the design WB. When the air has a lower WB, less air volume is required to do the same job. Since cooling towers must perform even at the worst conditions, and since actual conditions are better than the worst case 98% of the time, the air flow, and therefore the horsepower, required is much less than is built into the cooling tower.

Basically, the more water (and heat) to cool, the more air required to cool it. Also, the lower the inlet air WB to the cooling tower (the lower the inlet air heat content), the less air flow required to cool the water.

In some multicell mechanical-draft cooling towers, the isolation of individual cell air streams is ineffective because of one or more of the following:

- Partitions are missing or in need of repair.
- Partitions are incomplete or the water level is too low.

This condition results in temperature control problems. When one fan of a multicell tower is off, and another cell is running at half or full speed, a substantial amount of air comes from the cells which are off. The air bypasses the wetted fill, causing the fan to operate longer, hence reducing cooling tower efficiency. This problem can be corrected by the use of variable-speed fans. At thermal conditions less than design, all fans can be operated at the precise speed required to maintain the condenser water temperature. Thus, the cooling air will flow through the fill, even without partitions, and no more power will be expended than is necessary.

Some existing cooling towers at Fort Sill presently take advantage of two-speed fan control, but none take advantage of variable-speed cooling tower control.

Basis for Analysis:
The savings for this ECO were calculated with the following basis for analysis:

- The heat released by water must equal the heat absorbed by air in order for the cooling tower to function.

- An approximation is made from computer energy simulation runs of the hourly profile of building cooling loads.

(Continued)

CENTRAL PLANT 3442 ECO 5. (Continued)
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Basis for Analysis: (Continued)

- Knowing the performance of the tower and the ambient wet bulb temperature, the percent of design capacity can be calculated for each part load condition and WB temperature.

- Brake horsepower of the fan varies as the cube of the air flow. The difference in energy was calculated by taking into account the efficiency of the motor and variable-speed drive.

- The cost for variable-speed control was based on new variable-frequency, variable-speed drive retrofit to existing motors.

- Because there are four cells on this tower, two-speed control was not technically feasible.

Results:
5(A), Two-Speed Fan Retrofit: N/A

5(B), Variable-speed Retrofit:

Annual Electricity Savings (kWh):	35,884
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$492
Analysis Period:	25 Years
Estimated Construction Cost:	$10,499
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:
Two-speed fan control: N/A

Variable-speed fan control: Do not implement.

CENTRAL PLANT 3442 ECO 6.
INSTALL HIGH-EFFICIENCY MOTORS

Premise:
This ECO proposes to replace existing motors with high-efficiency motors to save electrical energy. The savings from installing high-efficiency motors are given by:

$$\text{Existing motor efficiency} = \frac{(hp * 0.746)}{(FLA * Volts * PF * \sqrt{3})}$$

$$\text{kW saved} = (Amps * Volts * PF * \sqrt{3}) * (1/\text{existing motor eff.} - 1/\text{new motor eff.})$$

$$\text{kWh saved per year} = (\text{kW saved} * \text{hours per year operation})$$

where:

hp = Nameplate horsepower of existing motor
0.746 = kW/hp
FLA = Nameplate full load amps
Amps = Measured amps of existing motor
Volts = Measured volts of existing motor
PF = Measured power factor of existing motor
√3 = Conversion for three phase power
New motor efficiency = from manufacturers' data

Basis for Analysis:
The savings for this ECO were calculated using the hours of motor operation, the existing motor efficiency, and the new motor efficiency. A spreadsheet was used to set up the appropriate formulas.

Results:

Annual Electricity Savings (kWh):	12,880
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$262
Analysis Period:	25 Years
Estimated Construction Cost:	$25,318
Simple Payback:	92 Years
Savings-to-Investment Ratio (SIR):	0.1

Recommendation:
Do not implement. The government should install high-efficiency motors any time the existing motors require replacement for other reasons.

4.6 CENTRAL PLANT 4701 EVALUATION

4.6.1 Baseline Energy Usage

Using the PC-CUBE program, Central Plant 4701 was evaluated to determine the baseline energy usage as the plant is currently operated. The baseline calculation considered heating and cooling loads, DHW loads, distribution losses, and central plant efficiencies. For this study, it was assumed Building 4700, currently a hospital, would be converted to an administration building.

The central plant operating procedures taken into account for the baseline calculation include:

- Chillers 1 and 2 (300 tons each) are both operated in the summer months.
- Boiler 1 is operated year-round to serve heating and DHW loads.

The evaluation assumed the plant to be connected to the proposed EMCS currently in design. The run-time hours of the chillers would be limited only to those hours required to serve Central Plant 4701 cooling loads when facilities are operating.

The results of the study indicate the two 300 ton chillers would operate a significant number of hours at 10% loading. The boiler loads indicate a peak loading of 80% for boiler 1 in the winter. The majority of operating hours for boiler 1 in the summer are at 11% to 20% loading.

The estimated annual baseline energy consumption and demand for chillers in Central Plant 4701 are:

- Total electrical consumption, 305,028 kWh.
- Peak electrical demand, 396 kW.

The estimated annual baseline energy consumption for boilers in Central Plant 4701 is:

- Total natural gas consumption, 9,595 MMBtu.

4.6.2 ECO Evaluation

CENTRAL PLANT 4701 ECO 1.
INSTALL INSTRUMENTATION TO ESTABLISH LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the chiller plant.

Chiller plant operators start and stop individual chillers based on their estimate of the daily weather and the chilled water return temperature. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the actual cooling load minimizes the amount of time extra chillers are operated unnecessarily. The energy savings result from:

- The difference in operating efficiency of the chillers operating at lower load than would be the case if they were more fully loaded.
- The difference in operating only the pumps and cooling towers required for the number of chillers to meet the load.

Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The chiller sequence of operation was changed from the sequence used in the baseline to a sequence in which chiller 1 is on until its rated capacity is reached, then chiller 2 is started and picks up the load in excess of the rated capacity of the first chiller.

The energy saved by this ECO is the difference between the baseline and ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	71,000
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$973
Analysis Period:	15 Years
Estimated Construction Cost:	$5,620
Simple Payback:	2.9 Years
Savings-to-Investment Ratio (SIR):	3.1

Recommendation: Implement.

CENTRAL PLANT 4701 ECO 2.
OPTIMIZE CHILLER OPERATION

Premise:
This ECO proposes to optimize chiller sequence of operation. Two chillers with different efficiencies operate to meet the chilled water load. Currently, the least efficient chiller operates the most hours. During the times when both chillers are not required, energy can be saved by operating the most efficient chiller.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The Chiller Identification Numbers were resequenced to simulate starting chillers in a different order.

The energy saved by this ECO was the difference between the baseline and the ECO simulations.

The cost was based on a one time minor repair project and on an annual maintenance contract to maintain chiller operation at peak efficiency.

Results:

Annual Electricity Savings (kWh):	178,000
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$2,439
Analysis Period:	15 Years
Estimated Construction Cost:	$16,929
Simple Payback:	7.3 Years
Savings-to-Investment Ratio (SIR):	1.2

Recommendation: Implement.

CENTRAL PLANT 4701 ECO 3.
INCREASE CHILLER EFFICIENCY

Premise:
This ECO proposes to replace the existing chillers to obtain a higher efficiency.

The existing chillers operate with efficiencies ranging from 0.97 kW per ton to 1.14 kW per ton. Design characteristics of a new high efficiency chiller indicate possible performance of 0.60 kW per ton at new condition. Performing minor repairs, cleaning, and other system modifications as necessary will maintain chiller operation at peak efficiency.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. New chiller performance data was entered in place of the tested performance data. The energy saved by this ECO is the difference between the baseline and the ECO simulations.

Results:

Annual Electricity Savings (kWh):	126,000
Peak Electrical Demand Savings (kW):	113
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$4,149
Analysis Period:	25 Years
Estimated Construction Cost:	$218,314
Simple Payback:	180 Years
Savings-to-Investment Ratio (SIR):	0.06

Recommendation: Do not implement.

CENTRAL PLANT 4701 ECO 4.
INSTALL ICE STORAGE SYSTEM

Premise:
This ECO proposes to install an ice storage system to reduce peak electrical energy use and cost.

The primary advantage of an ice storage system is the ability to use lower time-of-day electricity rates and off-peak demand rates to produce ice which can be used instead of chillers during times of peak electrical use. If the overall electrical peak demand can be reduced by shutting off chillers during peak periods, demand charges can be reduced for the whole year.

Basis for Analysis:
The savings of this ECO were hand calculated, based on the following assumptions.

- A reduction in chiller use of four hours per day is sufficient to reduce peak electrical demand.
- The reduction in demand will occur simultaneously with the overall base peak electrical demand.
- The auxiliary electrical loads imposed by the ice storage system offset the reduction in chiller auxiliary electrical use.
- The performance penalty due to the chillers producing ice instead of water at normal chilled water temperatures was not taken into consideration (best case scenario).
- The electrical demand savings are $1.787 per kW.

Cost and savings calculations are shown below:

Cost
= Tons capacity x hours per day x $60 per ton-hour
= 550 Tons x 4 hours per day x $60 per ton-hour
= $132,000

(Continued)

CENTRAL PLANT 4701 ECO 4. (Continued)
INSTALL ICE STORAGE SYSTEM

Annual Savings
= Tons capacity x kW per ton x $1.787 per kW-month x 12 months per year
= 550 Tons x 1.06 kW per ton x $1.787 per kW-month x 12 months per year
= $12,502

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	583
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$12,502
Analysis Period:	25 Years
Estimated Construction Cost:	$132,000
Simple Payback:	10.6 Years
Savings-to-Investment Ratio (SIR):	1.1

Recommendation: Implement.

CENTRAL PLANT 4701 ECO 5.
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Premise:
This ECO evaluates the use of two-speed fans and variable-speed fans as an alternative to save energy used by the cooling tower. A cooling tower fan drive is built to supply enough air to cool the water to a specified range, when the air is at the design WB. When the air has a lower WB, less air volume is required to do the same job. Since cooling towers must perform even at the worst conditions, and since actual conditions are better than the worst case 98% of the time, the air flow, and therefore the horsepower, required is much less than is built into the cooling tower.

Basically, the more water (and heat) to cool, the more air required to cool it. Also, the lower the inlet air WB to the cooling tower (the lower the inlet air heat content), the less air flow required to cool the water.

In some multicell mechanical-draft cooling towers, the isolation of individual cell air streams is ineffective because of one or more of the following:

- Partitions are missing or in need of repair.
- Partitions are incomplete or the water level is too low.

This condition results in temperature control problems. When one fan of a multicell tower is off, and another cell is running at half or full speed, a substantial amount of air comes from the cells which are off. The air bypasses the wetted fill, causing the fan to operate longer, hence reducing cooling tower efficiency. This problem can be corrected by the use of variable-speed fans. At thermal conditions less than design, all fans can be operated at the precise speed required to maintain the condenser water temperature. Thus, the cooling air will flow through the fill, even without partitions, and no more power will be expended than is necessary.

Some existing cooling towers at Fort Sill presently take advantage of two-speed fan control, but none take advantage of variable-speed cooling tower control.

Basis for Analysis:
The savings for this ECO were calculated with the following basis for analysis:

- The heat released by water must equal the heat absorbed by air in order for the cooling tower to function.

- An approximation is made from computer energy simulation runs of the hourly profile of building cooling loads.

(Continued)

CENTRAL PLANT 4701 ECO 5. (Continued)
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Basis for Analysis: (Continued)

- Knowing the performance of the tower and the ambient wet bulb temperature, the percent of design capacity can be calculated for each part load condition and wet bulb temperature.

- Brake horsepower of the fan varies as the cube of the air flow. The difference in energy was calculated by taking into account the efficiency of the motor and variable-speed drive.

- The cost for variable-speed control was based on new variable-frequency, variable-speed drive retrofit to existing motors.

- Because there are four cells to this tower, two-speed control was not technically feasible.

Results:
Two-Speed Fan Retrofit: N/A

Variable-speed Retrofit:

Annual Electricity Savings (kWh):	17,453
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$239
Analysis Period:	25 Years
Estimated Construction Cost:	$17,808
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:
Two-Speed Fan Control: N/A

Variable-Speed Fan Control: Do not implement.

CENTRAL PLANT 4701 ECO 6.
INSTALL HIGH-EFFICIENCY MOTORS

Premise:
This ECO proposes to replace existing motors with high-efficiency motors to save electrical energy. The savings from installing high-efficiency motors are given by:

$$\text{Existing motor efficiency} = \frac{(hp * 0.746)}{(FLA * Volts * PF * \sqrt{3})}$$

kW saved = (Amps * Volts * PF * √3) * (1/existing motor eff. - 1/new motor eff.)

kWh saved per year = (kW saved * hours per year operation)

where:

hp = Nameplate horsepower of existing motor
0.746 = kW per hp
FLA = Nameplate full load amps
Amps = Measured amps of existing motor
Volts = Measured volts of existing motor
PF = Measured power factor of existing motor
√3 = Conversion for three phase power
New motor efficiency = from manufacturers' data

Basis for Analysis:
The savings for this ECO were calculated using the hours of motor operation, the existing motor efficiency, and the new motor efficiency. A spreadsheet was used to set up the appropriate formulas.

Results:

Annual Electricity Savings (kWh):	4,605
Peak Electrical Demand Savings (kW):	3
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$127
Analysis Period:	25 Years
Estimated Construction Cost:	$18,176
Simple Payback:	136 Years
Savings-to-Investment Ratio (SIR):	0.08

Recommendation:
Do not implement. The government should install high-efficiency motors any time the existing motors require replacement for other reasons.

CENTRAL PLANT 4701 ECO 7.
INSTRUMENTATION TO ESTABLISH LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the boiler.

Boiler plant operators start and stop individual boilers based on their estimate of the daily weather. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the required heating capacity and the relevant controls allows minimizing the amount of time extra boilers are operated unnecessarily, thus lowering standby losses. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
Based on field survey observations and interviews with boiler operators, the boilers are operated at least 30 days more per year than the load requires. Running extra boilers has the effect of increasing standby losses.

The energy saved by this ECO is the energy lost by the boiler in standby for 30 days per year.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	61
Total Annual Utility Cost Savings:	$178
Analysis Period:	15 Years
Estimated Construction Cost:	$8,145
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 4701 ECO 8.
OPTIMIZE BOILER OPERATION

Premise:
This ECO proposes to optimize boiler operation by maximizing use of higher efficiency boilers. The three boilers in use operate with system efficiencies of 79%. Because the boilers operate near optimal efficiency and are sized equally, there is no benefit in resequencing boiler operation. This ECO is thus not applicable to Central Plant 4701.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 4701 ECO 9.
IMPROVE BOILER EFFICIENCY

Premise:
This ECO proposes to improve boiler efficiency by renovating or replacing boilers, associated equipment, and controls to reduce energy use. Based on combustion efficiency testing and field survey observations, the system efficiencies of the boilers are 79%. Because the boilers operate near optimal system efficiency, renovation or replacement will not significantly increase boiler efficiency. This ECO is thus not applicable for Central Plant 4701.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 4701 ECO 10.
INSTALL COMBUSTION CONTROLS

Premise:
This ECO proposes to install combustion controls to optimize the fuel-to-air ratio, increasing combustion efficiency and saving energy.

Based on combustion efficiency tests conducted during field surveys, boilers had excessive O_2 in the flue gas. This excessive O_2 transports more heat than necessary out of the boiler, decreasing efficiency and therefore the maximum useful output of a boiler.

Regular testing, by manual or automatic means, enables boiler operators to adjust the fuel-to-air ratio, thereby increasing boiler efficiency.

Depending on the level of energy savings, costs are estimated for manual or automatic testing equipment and controls.

Basis of Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Boiler efficiency inputs were adjusted to increase the maximum useful output of the boilers for a given fuel input. The energy savings of this ECO is the difference between the baseline and ECO energy simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	160
Total Annual Utility Cost Savings:	$467
Analysis Period:	15 Years
Estimated Construction Cost:	$24,869
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 4701 ECO 11.
INSTALL HIGH EFFICIENCY BURNERS

Premise:
All burners require excess air to ensure complete fuel combustion. The excess represents a loss because the boiler uses energy to heat it and it is emitted hot with the flue gas. Low excess air burners meeting burner environmental criteria minimize this type of loss. Combustion air requirements for low excess air burners vary with the firing rates; for low firing rates, excess air has to be increased. The percentage of increase varies substantially with the burner manufacturer. A burner that has relatively flat excess air requirements at low firing rates will reduce energy requirements.

Basis for Analysis:
EMC contacted numerous burner manufacturers' representatives and was not able to locate a burner with a small enough capacity to match these boilers. This ECO is thus not applicable for this central plant.

Results: N/A

Recommendation: N/A

CENTRAL PLANT 4701 ECO 12.
INSTALL STACK ECONOMIZER OR AIR PREHEATER

Premise:
This ECO proposes to install stack economizers or air preheaters to recover heat from the boiler stack and thereby save energy. Many of the boiler stack temperatures are high enough to allow significant heat loss. This ECO analyzes the economic feasibility of installing stack economizers to preheat feedwater to the boiler.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Based on published data, a 40°F rise in combustion air temperature decreases combustion efficiency by approximately 1%. The minimum stack temperature was estimated to be approximately 350°F. The existing stack temperatures were 408°F to 420°F. A 1% increase in maximum boiler output was input in the PC-CUBE to simulate this ECO. The energy saved by this ECO is the difference between the baseline and ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	89
Total Annual Utility Cost Savings:	$260
Analysis Period:	25 Years
Estimated Construction Cost:	$46,799
Simple Payback:	198 Years
Savings-to-Investment Ratio (SIR):	0.09

Recommendation: Do not implement.

CENTRAL PLANT 4701 ECO 14.
NEW PUMPS TO MATCH FLOW REQUIREMENTS

Premise:
Each chilled water pump in Building 4701 is designed to handle 550 tons of cooling. This is a properly sized load if both 275 ton chillers operate. However, with 275 tons of cooling load or less, running the excess flow is not required, and a smaller pump is needed. This ECO evaluated the installation of a single pump to handle one 275 ton chiller.

Basis for Analysis:
The energy savings from installing a smaller pump to handle the cooling load of one 275 ton chiller was determined by hand calculation. The flow was based on the tonnage and design TD for the 275 ton chiller. The required pressure drop for the smaller pump was assumed to be the same as the pressure drop for the existing main chilled water pumps. The horsepower of a smaller pump to meet the new flow requirements was calculated. The difference between the existing main chilled water pump kW and the proposed smaller pump kW was calculated based on an assumed pump and motor efficiency. The hours of operation for the smaller pump were taken from the PC-CUBE energy simulation base load computer run. Hours of operation were any hours when the cooling load on the chiller plant was 275 tons or less. The kW motor savings times the hours of operation were the potential kWh savings for this ECO.

Results:

Annual Electricity Savings (kWh):	50,401
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$690
Analysis Period:	25 Years
Estimated Construction Cost:	$21,168
Simple Payback:	29 Years
Savings-to-Investment Ratio (SIR):	0.39

Recommendation: Do not implement.

4.7 CENTRAL PLANT 5676 EVALUATION

4.7.1 Baseline Energy Usage

Using the PC-CUBE program, Central Plant 5676 was evaluated to determine the baseline energy usage as the plant is currently operated. The baseline calculation considered heating and cooling loads, DHW loads, and central plant efficiencies.

The central plant operating procedures taken into account for the baseline calculation include:

- Chiller 1 (170 tons) is operated in the summer months.
- Boilers 1 and 2 are operated year-round to serve heating loads.

The results of the study indicate the 170 ton chiller plant would operate a significant number of hours at 31% to 40% loading, with the maximum load reaching the current tested capacity. The study indicates peak loading for boiler 1, with the rest of the loads spread across the range for boiler 2, up to a maximum of 90%.

The estimated annual baseline energy consumption and demand for the chiller in Central Plant 5676 are:

- Total electrical consumption, 298,696 kWh.
- Peak electrical demand, 165 kW.

The estimated annual baseline energy consumption for boilers in Central Plant 5676 is:

- Total natural gas consumption, 13,463 MMBtu.

4.7.2 ECO Evaluation

CENTRAL PLANT 5676 ECO 1.
INSTALL INSTRUMENTATION TO ESTABLISH CHILLER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the chiller plant.

Chiller plant operators start and stop the chiller based on their estimate of the daily weather and the chilled water return temperature. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the actual cooling load minimizes the amount of time extra chillers are operated unnecessarily.

Because there are no extra chillers in Central Plant 5676, this ECO is not applicable.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 5676 ECO 2.
OPTIMIZE CHILLER OPERATION

Premise:
This ECO proposes to optimize chiller sequence of operation.

Because only one chiller is used to meet cooling loads, this ECO is not applicable to Central Plant 5676.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 5676 ECO 3.
INCREASE CHILLER EFFICIENCY

Premise:
This ECO proposes to replace the existing chiller to obtain a higher efficiency.

The existing chiller operates with an efficiency of 1.47 kW per ton. Design characteristics of a new high efficiency chiller indicate possible performance of 0.60 kW per ton at new condition. Performing minor repairs, cleaning, and other system modifications as necessary will keep the efficiency of the chiller at its optimum.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. New chiller performance data was entered in place of the tested performance data. The energy saved by this ECO is the difference between the baseline and the ECO simulations.

Results:

Annual Electricity Savings (kWh):	137,000
Peak Electrical Demand Savings (kW):	96
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$3,936
Analysis Period:	25 Years
Estimated Construction Cost:	$94,320
Simple Payback:	96 Years
Savings-to-Investment Ratio (SIR):	0.12

Recommendation: Do not implement.

CENTRAL PLANT 5676 ECO 4.
INSTALL ICE STORAGE COOLING SYSTEM

Premise:
This ECO proposes to install an ice storage cooling system to reduce peak air conditioning electrical demand (load shifting) and cost.

The primary advantage of an ice storage cooling system is the ability to use lower time-of-day electricity rates and off-peak demand rates to produce ice which can be used instead of chillers to provide cooling for HVAC equipment during times of peak electrical use. Fort Sill does not have this type of rate structure; however, if the overall peak electrical demand can be reduced by shutting off chillers during peak periods, demand charges can be reduced for the whole year.

Basis for Analysis:
The savings of this ECO were calculated, based on the following assumptions.

- A reduction in chiller use of four hours per day is sufficient to reduce peak electrical demand.
- The reduction in demand will occur simultaneously with the overall base peak electrical demand.
- The auxiliary electrical loads imposed by the ice storage system offset the reduction in chiller auxiliary electrical use.
- The performance penalty due to the chillers producing ice instead of water at normal chilled water temperatures was not taken into consideration (best case scenario).
- The electrical demand savings are $1.787 per kW.

Cost and savings calculations are shown below:

Cost
= Tons capacity x hours per day x $60 per ton-hour
= 170 Tons x 4 hours per day x $60 per ton-hour
= $40,800

(Continued)

CENTRAL PLANT 5676 ECO 4. (Continued)
INSTALL ICE STORAGE SYSTEM

Annual Savings
= Tons capacity x kW per ton x $1.787 per kW-month x 12 months per year
= 170 Tons x 1.47 kW per ton x $1.787 per kW-month 12 months per year
= $5,359

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	250
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$5,359
Analysis Period:	25 Years
Estimated Construction Cost:	$40,800
Simple Payback:	7.6 Years
Savings-to-Investment Ratio (SIR):	1.53

Recommendation: Implement.

CENTRAL PLANT 5676 ECO 5.
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Premise:
This ECO evaluates the use of two-speed fans and variable-speed fans as an alternative to save energy used by the cooling tower. A cooling tower fan drive is built to supply enough air to cool the water to a specified range, when the air is at the design WB. When the air has a lower WB, less air volume is required to do the same job. Since cooling towers must perform even at the worst conditions, and since actual conditions are better than the worst case 98% of the time, the air flow, and therefore the horsepower, required is much less than is built into the cooling tower.

Basically, the more water (and heat) to cool, the more air required to cool it. Also, the lower the inlet air WB to the cooling tower (the lower the inlet air heat content), the less air flow required to cool the water.

In some multicell mechanical-draft cooling towers, the isolation of individual cell air streams is ineffective because of one or more of the following:

- Partitions are missing or in need of repair.
- Partitions are incomplete or the water level is too low.

This condition results in temperature control problems. When one fan of a multicell tower is off, and another cell is running at half or full speed, a substantial amount of air comes from the cells which are off. The air bypasses the wetted fill, causing the fan to operate longer, hence reducing cooling tower efficiency. This problem can be corrected by the use of variable-speed fans. At thermal conditions less than design, all fans can be operated at the precise speed required to maintain the condenser water temperature. Thus, the cooling air will flow through the fill, even without partitions, and no more power will be expended than is necessary.

Some existing cooling towers at Fort Sill presently take advantage of two-speed fan control, but none take advantage of variable-speed cooling tower control.

Basis for Analysis:
The savings for this ECO were calculated with the following basis for analysis:

- The heat released by water must equal the heat absorbed by air in order for the cooling tower to function.

- An approximation is made from computer energy simulation runs of the hourly profile of building cooling loads.

(Continued)

CENTRAL PLANT 5676 ECO 5. (Continued)
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Basis for Analysis: (Continued)

- Knowing the performance of the tower and the ambient wet bulb temperature, the percent of design capacity can be calculated for each part load condition and wet bulb temperature.

- The number of stages of control for the two-speed fan retrofit was calculated based on the number of existing tower fans.

- Brake horsepower of the fan varies as the cube of the air flow. The difference in energy was calculated by taking into account the efficiency of the motor and variable-speed drive.

- The cost for two-speed control was based on new motors and controls for existing towers.

- The cost for variable-speed control was based on new variable-frequency, variable-speed drive retrofit to existing motors.

Results:

5(A), Two-Speed Fan Retrofit:

Annual Electricity Savings (kWh):	4,100
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$56
Analysis Period:	25 Years
Estimated Construction Cost:	$4,296
Simple Payback:	73 Years
Savings-to-Investment Ratio (SIR):	0.2

5(B), Variable-speed Retrofit:

Annual Electricity Savings (kWh):	4,970
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$68
Analysis Period:	25 Years
Estimated Construction Cost:	$5,076
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:

Two-speed fan control: Do not implement.

Variable-speed fan control: Do not implement.

CENTRAL PLANT 5676 ECO 6.
INSTALL HIGH-EFFICIENCY MOTORS

Premise:
This ECO proposes to replace existing motors with new high-efficiency motors to save electrical energy. The savings from installing high-efficiency motors are given by:

$$\text{Existing motor efficiency} = \frac{(hp * 0.746)}{(FLA * Volts * PF * \sqrt{3})}$$

kW saved = (Amps * Volts * PF * √3) * (1/existing motor eff. - 1/new motor eff.)

kWh saved per year = (kW saved * hours per year operation)

where:

hp = Nameplate horsepower of existing motor
0.746 = kW per hp
FLA = Nameplate full load amps
Amps = Measured amps of existing motor
Volts = Measured volts of existing motor
PF = Measured power factor of existing motor
√3 = Conversion for three phase power
New motor efficiency = from manufacturers' data

Basis for Analysis:
The savings for this ECO were calculated using the hours of motor operation, the existing motor efficiency, and the new motor efficiency. A spreadsheet was used to set up the appropriate formulas.

Results:

Annual Electricity Savings (kWh):	24,287
Peak Electrical Demand Savings (kW):	4
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$419
Analysis Period:	25 Years
Estimated Construction Cost:	$4,797
Simple Payback:	10.9 Years
Savings-to-Investment Ratio (SIR):	1.05

Recommendation: Implement.

CENTRAL PLANT 5676 ECO 7.
INSTRUMENTATION TO ESTABLISH BOILER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the boiler.

Boiler plant operators start and stop individual boilers based on their estimate of the daily weather. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the required heating capacity and the relevant controls allows minimizing the amount of time extra boilers are operated unnecessarily, thus lowering standby losses. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
Based on field survey observations and interviews with boiler operators, the boilers are operated at least 30 days more per year than the load requires. Running extra boilers has the effect of increasing standby losses.

The energy saved by this ECO is the energy lost by the boiler in standby for 30 days per year.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	13
Total Annual Utility Cost Savings:	$38
Analysis Period:	15 Years
Estimated Construction Cost:	$5,620
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 5676 ECO 8.
OPTIMIZE BOILER OPERATION

Premise:
This ECO proposes to optimize boiler operation by maximizing use of higher efficiency boilers. The two boilers in use have system efficiencies ranging from 71% to 75%. Because the boilers are sequencing to operate the most efficient first, and the least efficient last, there is no benefit in resequencing boiler operation. This ECO is not applicable to Central Plant 5676.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 5676 ECO 9.
IMPROVE BOILER EFFICIENCY

Premise:
This ECO proposes to improve boiler efficiency by replacing boilers, associated equipment, and controls to reduce energy use. Based on combustion efficiency testing and field survey observations, the system efficiencies of the existing boilers range from 71% to 75%. Installing new boilers and associated controls will increase system efficiencies and save energy.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. New boilers rated at 80% efficiency were simulated in place of the existing boilers. The energy savings of this ECO are the difference between the baseline and ECO energy simulation.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	5,520
Total Annual Utility Cost Savings:	$16,118
Analysis Period:	25 Years
Estimated Construction Cost:	$105,344
Simple Payback:	11.8 Years
Savings-to-Investment Ratio (SIR):	1.6

Recommendation: Implement.

CENTRAL PLANT 5676 ECO 10.
INSTALL COMBUSTION CONTROLS

Premise:
This ECO proposes to install combustion controls to optimize the fuel-to-air ratio, increasing combustion efficiency and saving energy.

Based on combustion efficiency tests conducted during field surveys, boilers had excessive O_2 in the flue gas. This excessive O_2 transports more heat than necessary out of the boiler, decreasing efficiency and therefore the maximum useful output of a boiler.

Regular testing, by manual or automatic means, enables boiler operators to adjust the fuel-to-air ratio, thereby increasing boiler efficiency.

Depending on the level of energy savings, costs are estimated for manual or automatic testing equipment and controls.

Basis of Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Boiler efficiency inputs were adjusted to increase the maximum useful output of the boilers for a given fuel input. The energy savings of this ECO is the difference between the baseline and the ECO energy simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	238
Total Annual Utility Cost Savings:	$695
Analysis Period:	15 Years
Estimated Construction Cost:	$24,869
Simple Payback:	21 Years
Savings-to-Investment Ratio (SIR):	0.33

Recommendation: Do not implement.

CENTRAL PLANT 5676 ECO 11.
INSTALL HIGH EFFICIENCY BURNERS

Premise:
All burners require excess air to ensure complete fuel combustion. The excess air represents a loss because the boiler uses energy to heat it, and it is emitted hot with the flue gas. Low excess air burners meeting environmental criteria minimize this type of loss. Combustion air requirements for low excess air burners vary with the firing rates; for low firing rates, excess air must be increased. The percentage of increase varies substantially with the burner manufacturer. A burner that has relatively flat excess air requirements at low firing rates will reduce energy requirements.

Basis for Analysis:
EMC contacted manufacturers of numerous burner representatives; however, it was not possible to locate a burner with a capacity small enough to match these boilers. This ECO is thus not applicable for this central plant.

Results: N/A

Recommendation: N/A

CENTRAL PLANT 5676 ECO 12.
INSTALL STACK ECONOMIZER OR AIR PREHEATER

Premise:
This ECO proposes to install stack economizers or air preheaters to recover heat from the boiler stack and thereby save energy. Many of the boiler stack temperatures are high enough to allow significant heat loss. This ECO analyzes the economic feasibility of installing stack economizers to preheat feedwater to the boiler.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Based on published data, a 40°F rise in combustion air temperature decreases combustion efficiency by approximately 1%. The minimum stack temperature was estimated to be approximately 350°F. The existing stack temperatures are 560°F on boiler 1 and 690°F on boiler 2. A 5% increase in efficiency would be possible for boiler 1 and a 9% increase in efficiency would be possible for boiler 2. The energy saved by this ECO is the difference between the baseline and the ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	718
Total Annual Utility Cost Savings:	$2,097
Analysis Period:	25 Years
Estimated Construction Cost:	$31,635
Simple Payback:	14.02 Years
Savings-to-Investment Ratio (SIR):	1.25

Recommendation: Implement.

4.8 CENTRAL PLANT 5678 EVALUATION

4.8.1 Baseline Energy Usage

Using the PC-CUBE program, Central Plant 5678 was evaluated to determine the baseline energy usage as the central plant is currently operated. The baseline calculation considered heating and cooling loads, DHW loads, and central plant efficiencies.

The central plant operating procedures taken into account for the baseline calculation include:

- Chiller 1 (190 tons) is operated in the summer months.
- Boilers 1 and 2 are operated year-round to serve heating and DHW loads.

According to the study results, the 190 ton chiller plant would operate a significant number of hours at 21% to 30% loading. The study indicates peak loading for boiler 1; for boiler 2, the loads are spread across the range.

The estimated annual baseline energy consumption and demand for the chiller in Central Plant 5678 are:

- Total electrical consumption, 233,241 kWh.
- Peak electrical demand, 106 kW.

The estimated annual baseline energy consumption for boilers in Central Plant 5678 is:

- Total natural gas consumption, 16,330 MMBtu.

4.8.2 ECO Evaluation

CENTRAL PLANT 5678 ECO 1.
INSTALL INSTRUMENTATION TO ESTABLISH COOLING LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the chiller plant.

Chiller plant operators start and stop the chiller based on their estimate of the daily weather and the chilled water return temperature. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the actual cooling load minimizes the amount of time extra chillers are operated unnecessarily.

Because there are no extra chillers in Central Plant 5678, this ECO is not applicable.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 5678 ECO 2.
OPTIMIZE CHILLER OPERATION

Premise:
This ECO proposes to optimize chiller sequence of operation.

Because only one chiller is used to meet cooling loads, this ECO is not applicable to Central Plant 5678.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 5678 ECO 3.
INCREASE CHILLER EFFICIENCY

Premise:
This ECO proposes to repair the chiller to obtain a higher efficiency.

The chiller operates with an efficiency of 0.71 kW per ton. Because this chiller operates near its design efficiency, this ECO is not applicable to Central Plant 5678. The problems noted with this chiller should be corrected to assure it can obtain its rated nominal capacity.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 5678 ECO 4.
INSTALL ICE STORAGE COOLING SYSTEM

Premise:
This ECO proposes to install an ice storage cooling system to reduce peak air conditioning electrical demand (load shifting) and cost.

The primary advantage of an ice storage cooling system is the ability to use lower time-of-day electricity rates and off-peak demand rates to produce ice which can be used instead of chillers to provide cooling for HVAC equipment during times of peak electrical use. Fort Sill does not have this type of rate structure; however, if the overall peak electrical demand can be reduced by shutting off chillers during peak periods, demand charges can be reduced for the whole year.

Basis for Analysis:
The savings of this ECO are hand calculated, based on the following assumptions for a best case analysis:

- A reduction in chiller use of four hours per day is sufficient to reduce peak electrical demand.
- The reduction in demand will occur simultaneously with the overall base peak electrical demand.
- The auxiliary electrical loads imposed by the ice storage system exactly offset the reduction in chiller auxiliary electrical use.
- The performance penalty due to the chillers producing ice instead of water at normal chilled water temperatures was not taken into consideration (best case scenario).
- The electrical demand savings are $1.787 per kW.

Cost and savings calculations are shown below:

Cost
= Tons capacity x hours per day x $60 per ton-hour
= 200 Tons x 4 hours per day x $60 per ton-hour
= $48,000

(Continued)

CENTRAL PLANT 5678 ECO 4. (Continued)
INSTALL ICE STORAGE SYSTEM

Annual Savings
= Tons capacity x kW per ton x $1.787 per kW-month x 12 months per year
= 200 Tons x 0.71 kW per ton x $1.787 per kW-month x 12 months per year
= $3,045

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	142
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$3,045
Analysis Period:	25 Years
Estimated Construction Cost:	$48,000
Simple Payback:	15.8 Years
Savings-to-Investment Ratio (SIR):	0.7

Recommendation: Do not implement.

CENTRAL PLANT 5678 ECO 5.
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Premise:
This ECO evaluates the use of two-speed fans and variable-speed fans as an alternative to save energy used by the cooling tower. A cooling tower fan drive is built to supply enough air to cool the water to a specified range, when the air is at the design WB. When the air has a lower WB, less air volume is required to do the same job. Since cooling towers must perform even at the worst conditions, and since actual conditions are better than the worst case 98% of the time, the air flow, and therefore the horsepower, required is much less than is built into the cooling tower.

Basically, the more water (and heat) to cool, the more air required to cool it. Also, the lower the inlet air WB to the cooling tower (the lower the inlet air heat content), the less air flow required to cool the water.

In some multicell mechanical-draft cooling towers, the isolation of individual cell air streams is ineffective because of one or more of the following:

- Partitions are missing or in need of repair.
- Partitions are incomplete or the water level is too low.

This condition results in temperature control problems. When one fan of a multicell tower is off, and another cell is running at half or full speed, a substantial amount of air comes from the cells which are off. The air bypasses the wetted fill, causing the fan to operate longer, hence reducing cooling tower efficiency. This problem can be corrected by the use of variable-speed fans. At thermal conditions less than design, all fans can be operated at the precise speed required to maintain the condenser water temperature. Thus, the cooling air will flow through the fill, even without partitions, and no more power will be expended than is necessary.

Some existing cooling towers at Fort Sill presently take advantage of two-speed fan control, but none take advantage of variable-speed cooling tower control.

Basis for Analysis:
The savings for this ECO were calculated with the following basis for analysis:

- The heat released by water must equal the heat absorbed by air in order for the cooling tower to function.

- An approximation is made from computer energy simulation runs of the hourly profile of building cooling loads.

(Continued)

CENTRAL PLANT 5678 ECO 5. (Continued)
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Basis for Analysis: (Continued)

- Knowing the performance of the tower and the ambient wet bulb temperature, the percent of design capacity can be calculated for each part load condition, and wet bulb temperature.
- The number of stages of control for the two-speed fan retrofit was calculated based on the number of existing tower fans.
- Brake horsepower of the fan varies as the cube of the air flow. The difference in energy was calculated by taking into account the efficiency of the motor and variable-speed drive.
- The cost for two-speed control was based on new motors and controls for existing towers.
- The cost for variable-speed control was based on new variable-frequency, variable-speed drive retrofit to existing motors.

Results:

5(A), Two-Speed Fan Retrofit:

Annual Electricity Savings (kWh):	3,873
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$53
Analysis Period:	25 Years
Estimated Construction Cost:	$4,296
Simple Payback:	77 Years
Savings-to-Investment Ratio (SIR):	0.1

5(B), Variable-speed Retrofit:

Annual Electricity Savings (kWh):	4,721
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$65
Analysis Period:	25 Years
Estimated Construction Cost:	$5,076
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:

Two-speed fan control: Do not implement.

Variable-speed fan control: Do not implement.

CENTRAL PLANT 5678 ECO 6.
INSTALL HIGH-EFFICIENCY MOTORS

Premise:
This ECO proposes to replace existing motors with high-efficiency motors to save electrical energy. The savings from installing high-efficiency motors are given by:

$$\text{Existing motor efficiency} = \frac{(hp * 0.746)}{(FLA * Volts * PF * \sqrt{3})}$$

$$\text{kW saved} = (Amps * Volts * PF * \sqrt{3}) * (1/\text{existing motor eff.} - 1/\text{new motor eff.})$$

$$\text{kWh saved per year} = (\text{kW saved} * \text{hours per year operation})$$

where:

- hp = Nameplate horsepower of existing motor
- 0.746 = kW/hp
- FLA = Nameplate full load amps
- Amps = Measured amps of existing motor
- Volts = Measured volts of existing motor
- PF = Measured power factor of existing motor
- $\sqrt{3}$ = Conversion for three phase power
- New motor efficiency = from manufacturers' data

Basis for Analysis:
The savings for this ECO were calculated using the hours of motor operation, the existing motor efficiency, and the new motor efficiency. A spreadsheet was used to set up the appropriate formulas.

Results:

Annual Electricity Savings (kWh):	14,412
Peak Electrical Demand Savings (kW):	3
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$261
Analysis Period:	25 Years
Estimated Construction Cost:	$4,821
Simple Payback:	17 Years
Savings-to-Investment Ratio (SIR):	0.6

Recommendation:
Do not implement. The government should install high-efficiency motors any time the existing motors require replacement for other reasons.

CENTRAL PLANT 5678 ECO 7.
INSTRUMENTATION TO ESTABLISH BOILER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the boiler.

Boiler plant operators start and stop individual boilers based on their estimate of the daily weather. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the required heating capacity and the relevant controls allows minimizing the amount of time extra boilers are operated unnecessarily, thus lowering standby losses. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
Based on field survey observations and interviews with boiler operators, the boilers are operated at least 30 days more per year than the load requires. Running extra boilers has the effect of increasing standby losses.

The energy saved by this ECO is the energy lost by the boiler in standby for 30 days per year.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	11
Total Annual Utility Cost Savings:	$32
Analysis Period:	15 Years
Estimated Construction Cost:	$5,620
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 5678 ECO 8.
OPTIMIZE BOILER OPERATION

Premise:
This ECO proposes to optimize boiler operation by maximizing use of higher efficiency boilers. The two boilers in use operate with system efficiencies ranging from 68% to 73%. The boiler with the lowest efficiency operates a majority of the heating season hours, while higher efficiency boiler remains idle. Resequencing the higher efficiency boiler to operate more hours will save energy.

Basis for Analysis:
The PC-CUBE energy simulation was used to analyze this ECO. The boiler sequence was changed from the baseline sequence to operate the most efficient boiler first, to the least efficient last. The energy saved by this ECO is the difference between the baseline and ECO computer simulation.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	272
Total Annual Utility Cost Savings:	$794
Analysis Period:	15 Years
Estimated Construction Cost:	$28,699
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 5678 ECO 9.
IMPROVE BOILER EFFICIENCY

Premise:
This ECO proposes to improve boiler efficiency by replacing boilers, associated equipment, and controls to reduce energy use. Based on combustion efficiency testing and field survey observations, the system efficiencies of the existing boilers range from 68% to 73%. Installing new boilers and associated controls will increase system efficiencies and save energy.

Basis for Analysis:
The PC-CUBE energy simulation program is used to analyze this ECO. New boilers rated at 80% efficiency were simulated in place of the existing boilers. The energy savings of this ECO are the difference between the baseline and the ECO energy simulation.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	14,980
Total Annual Utility Cost Savings:	$43,742
Analysis Period:	25 Years
Estimated Construction Cost:	$105,344
Simple Payback:	7.6 Years
Savings-to-Investment Ratio (SIR):	2.4

Recommendation: Implement.

CENTRAL PLANT 5678 ECO 10.
INSTALL COMBUSTION CONTROLS

Premise:
This ECO proposes to install combustion controls to optimize the fuel-to-air ratio, increasing combustion efficiency and saving energy.

Based on combustion efficiency tests conducted during field surveys, boilers had excessive O_2 in the flue gas. This excessive O_2 transports more heat than necessary out of the boiler, decreasing efficiency and therefore the maximum useful output of a boiler.

Regular testing, by manual or automatic means, enables boiler operators to adjust the fuel-to-air ratio, thereby increasing boiler efficiency.

Depending on the level of energy savings, costs are estimated for manual or automatic testing equipment and controls.

Basis of Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Boiler efficiency inputs were adjusted to increase the maximum useful output of the boilers for a given fuel input. The energy savings of this ECO is the difference between the baseline and the ECO energy simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	1,537
Total Annual Utility Cost Savings:	$4,488
Analysis Period:	15 Years
Estimated Construction Cost:	$1,799
Simple Payback:	8.8 Years
Savings-to-Investment Ratio (SIR):	1.7

Recommendation: Implement.

CENTRAL PLANT 5678 ECO 11.
INSTALL HIGH EFFICIENCY BURNERS

Premise:
All burners require excess air to ensure complete fuel combustion. The excess air represents a loss because the boiler uses energy to heat it, and it is emitted hot with the flue gas. Low excess air burners meeting environmental criteria minimize this type of loss. Combustion air requirements for low excess air burners vary with the firing rates; for low firing rates, excess air must be increased. The percentage of increase varies substantially with the burner manufacturer. A burner that has relatively flat excess air requirements at low firing rates will reduce energy requirements.

Basis for Analysis:
EMC contacted manufacturers of numerous burner representatives; however, it was not possible to locate a burner with a capacity small enough to match these boilers. This ECO is thus not applicable for this central plant.

Results: N/A

Recommendation: N/A

CENTRAL PLANT 5678 ECO 12.
INSTALL STACK ECONOMIZER OR AIR PREHEATER

Premise:
This ECO proposes to install stack economizers or air preheaters to recover heat from the boiler stack and thereby save energy. Many of the boiler stack temperatures are high enough to allow significant heat loss.

Basis for Analysis:
The PC-CUBE energy simulation program is used to analyze this ECO. Based on published data, a 40°F rise in combustion air temperature decreases combustion efficiency by approximately 1%. The minimum stack temperature is estimated to be approximately 350°F. The existing stack temperatures are 380°F on boiler 1 and 410°F on boiler 2. A 1% increase in efficiency would be possible for boiler 1 and boiler 2. The energy saved by this ECO is the difference between the baseline and the ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	196
Total Annual Utility Cost Savings:	$572
Analysis Period:	25 Years
Estimated Construction Cost:	$31,635
Simple Payback:	53 Years
Savings-to-Investment Ratio (SIR):	0.3

Recommendation: Do not implement.

4.9 CENTRAL PLANT 5900 EVALUATION

4.9.1 Baseline Energy Usage

Using the PC-CUBE program, Central Plant 5900 was evaluated to determine the baseline energy usage as the plant is currently operated. The baseline calculations considered heating and cooling loads, DHW loads, distribution losses, and Central Plant efficiencies.

The central plant operating procedures taken into account for the baseline calculation included:

- Chillers 1, 2, 3, 4, and 5 are operated in the summer months in various numbers to serve the load.

- Because there is no instrumentation, the operators run more chillers than required to meet the load.

- The operators run an extra chilled water pump, without running its corresponding chiller.

- Boilers 1, 2, and 3, are operated in the winter months.

- The boilers are off in the summer. DHW loads are served by a small package boiler in each individual building (not included in this study).

The estimated annual baseline energy consumption and demand for chillers in Central Plant 5900 are:

- Total electrical consumption, 2,743,132 kWh.
- Peak electrical demand, 1,886 kW.

The estimated annual baseline energy consumption for boilers in Central Plant 5900 is:

- Total natural gas consumption, 172,256 MMBtu.

4.9.2 ECO Evaluation

CENTRAL PLANT 5900 ECO 1.
INSTALL INSTRUMENTATION TO ESTABLISH CHILLER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the chiller plant.

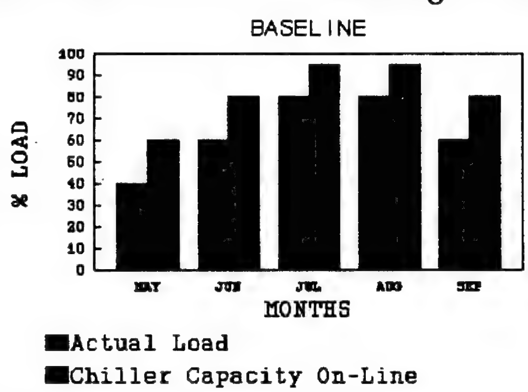
Chiller plant operators start and stop individual chillers based on their estimate of the daily weather and the chilled water return temperature. This estimate occurs periodically during the day.

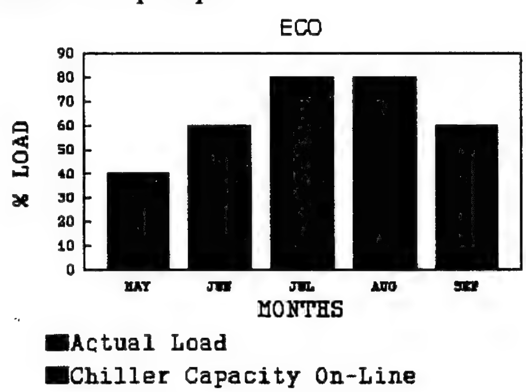
Installing instrumentation to establish the actual cooling load minimizes the amount of time extra chillers are operated unnecessarily. The energy savings result from:

- The difference in operating efficiency of the chillers operating at lower load than would be the case if they were more fully loaded.
- The difference in operating only the pumps and cooling towers required for the number of chillers to meet the load.

Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The chiller sequence of operation was changed from the sequence used in the baseline to a sequence in which chiller 1 is on until its rated capacity is reached, then chiller 2 is started and picks up the load in excess of the rated capacity of the first chiller. This ECO also took into account eliminating excess operation of pumps.





(Continued)

CENTRAL PLANT 5900 ECO 1. (Continued)
INSTALL INSTRUMENTATION TO ESTABLISH CHILLER LOAD

The energy saved by this ECO is the difference between the baseline and ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	519,000
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$7,112
Analysis Period:	15 Years
Estimated Construction Cost:	$5,620
Simple Payback:	0.8 Years
Savings-to-Investment Ratio (SIR):	11

Recommendations: Implement.

CENTRAL PLANT 5900 ECO 2.
OPTIMIZE CHILLER OPERATION

Premise:
This ECO proposes to optimize chiller sequence of operation. Up to five chillers with different efficiencies operate to meet the chilled water load. Currently, two of the least efficient chillers operate the most hours. During the times when all five chillers are not required, energy can be saved by operating the most efficient chillers.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The Chiller Identification Numbers were resequenced to simulate starting chillers in a different order. The energy saved by this ECO is the difference between the baseline and the ECO simulations.

Results:

Annual Electricity Savings (kWh):	539,000
Peak Electrical Demand Savings (kW):	9
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$7,583
Analysis Period:	15 Years
Estimated Construction Cost:	$20,887
Simple Payback:	3.1 Years
Savings-to-Investment Ratio (SIR):	2.8

Recommendations: Implement.

CENTRAL PLANT 5900 ECO 3.
INCREASE CHILLER EFFICIENCY

Premise:
This ECO proposes to repair the existing chiller to obtain a higher efficiency.

The five chillers operate with efficiencies ranging from 0.85 kW per ton to 0.94 kW per ton. Design characteristics of the chillers indicate possible performances of 0.66 kW per ton to 0.85 kW per ton. Performing minor repairs, cleaning, and other system modifications as necessary will increase chiller efficiencies.

Basis for Analysis:
The PC-CUBE energy simulation program is used to analyze this ECO. Near new chiller performance data was entered in place of the tested performance data. The energy saved by this ECO is the difference between the baseline and the ECO simulations.

The cost was based on a one time minor repair project, installing a new cooling tower on chiller 1, and an annual maintenance contract to maintain chiller operation at peak efficiency.

Results:

Annual Electricity Savings (kWh):	718,000
Peak Electrical Demand Savings (kW):	154
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$13,139
Analysis Period:	15 Years
Estimated Construction Cost:	$49,465
Simple Payback:	15 Years
Savings-to-Investment Ratio (SIR):	0.6

Recommendations:
Although the analysis indicates this, as an ECO, would not meet ECIP criteria based soley on energy savings, it is strongly recommended that the chiller be repaired, and maintained at optimum efficiency. If not, it will continue to deteriorate, operate even less efficiently, and fail, which will result in major repair or replacement costs.

CENTRAL PLANT 5900 ECO 4.
INSTALL ICE STORAGE COOLING SYSTEM

Premise:
This ECO proposes to install an ice storage cooling system to reduce peak air conditioning electrical demand (load shifting) and cost.

The primary advantage of an ice storage cooling system is the ability to use lower time-of-day electricity rates and off-peak demand rates to produce ice which can be used instead of chillers to provide cooling for HVAC equipment during times of peak electrical use. Fort Sill does not have this type of rate structure; however, if the overall peak electrical demand can be reduced by shutting off chillers during peak periods, demand charges can be reduced for the whole year.

Basis for Analysis:
The savings of this ECO were calculated, based on the following assumptions.

- A reduction in chiller use of four hours per day is sufficient to reduce peak electrical demand.
- The reduction in demand will occur simultaneously with the overall base peak electrical demand.
- The auxiliary electrical loads imposed by the ice storage system offset the reduction in chiller auxiliary electrical use.
- The performance penalty due to the chillers producing ice instead of water at normal chilled water temperatures was not taken into consideration (best case scenario).
- The electrical demand savings are $1.787 per kW.

Cost and savings calculations are shown below:

Cost
= Tons capacity x hours per day x $60 per ton-hour
= 2,100 Tons x 4 hours per day x $60 per ton-hour
= $504,000

(Continued)

CENTRAL PLANT 5900 ECO 4. (Continued)
INSTALL ICE STORAGE SYSTEM

Annual Savings

= Tons capacity x kW per ton x $1.787 per kW-month x 12 months per year
= 2,100 Tons x 0.90 kW per ton x $1.787 per kW-month x 12 months per year
= $40,529

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	1,890
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$40,529
Analysis Period:	25 Years
Estimated Construction Cost:	$504,000
Simple Payback:	12.4 Years
Savings-to-Investment Ratio (SIR):	0.94

Recommendations: Do not implement.

CENTRAL PLANT 5900 ECO 5.
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Premise:
This ECO evaluates the use of two-speed fans and variable-speed fans as an alternative to save energy used by the cooling tower. A cooling tower fan drive is built to supply enough air to cool the water to a specified range, when the air is at the design WB. When the air has a lower WB, less air volume is required to do the same job. Since cooling towers must perform even at the worst conditions, and since actual conditions are better than the worst case 98% of the time, the air flow, and therefore the horsepower, required is much less than is built into the cooling tower.

Basically, the more water (and heat) to cool, the more air required to cool it. Also, the lower the inlet air WB to the cooling tower (the lower the inlet air heat content), the less air flow required to cool the water.

In some multicell mechanical-draft cooling towers, the isolation of individual cell air streams is ineffective because of one or more of the following:

- Partitions are missing or in need of repair.
- Partitions are incomplete or the water level is too low.

This condition results in temperature control problems. When one fan of a multicell tower is off, and another cell is running at half or full speed, a substantial amount of air comes from the cells which are off. The air bypasses the wetted fill, causing the fan to operate longer, hence reducing cooling tower efficiency. This problem can be corrected by the use of variable-speed fans. At thermal conditions less than design, all fans can be operated at the precise speed required to maintain the condenser water temperature. Thus, the cooling air will flow through the fill, even without partitions, and no more power will be expended than is necessary.

Some existing cooling towers at Fort Sill presently take advantage of two-speed fan control, but none take advantage of variable-speed cooling tower control.

Basis for Analysis:
The savings for this ECO were calculated with the following basis for analysis:

- The heat released by water must equal the heat absorbed by air in order for the cooling tower to function.

- An approximation is made from computer energy simulation runs of the hourly profile of building cooling loads.

(Continued)

CENTRAL PLANT 5900 ECO 5. (Continued)
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Basis for Analysis: (Continued)

- Knowing the performance of the tower and the ambient wet bulb temperature, the percent of design capacity can be calculated for each part load condition, and wet bulb temperature.

- The number of stages of control for the two-speed fan retrofit was calculated based on the number of existing tower fans.

- Brake horsepower of the fan varies as the cube of the air flow. The difference in energy was calculated by taking into account the efficiency of the motor and variable-speed drive.

- The cost for two-speed control was based on new motors and controls for existing towers.

- The cost for variable-speed control was based on new variable-frequency, variable-speed drive retrofit to existing motors.

Results:

5(A), Two-Speed Fan Retrofit:

Annual Electricity Savings (kWh):	15,915
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$218
Analysis Period:	25 Years
Estimated Construction Cost:	$8,154
Simple Payback:	35.6 Years
Savings-to-Investment Ratio (SIR):	0.3

5(B), Variable-Speed Retrofit:

Annual Electricity Savings (kWh):	21,175
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$290
Analysis Period:	25 Years
Estimated Construction Cost:	$7,469
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:

Two-speed fan control: Do not implement.

Variable-speed fan control: Do not implement.

CENTRAL PLANT 5900 ECO 6.
INSTALL HIGH-EFFICIENCY MOTORS

Premise:
This ECO proposes to replace existing motors with high-efficiency motors to save electrical energy. The savings from installing high-efficiency motors are given by:

$$\text{Existing motor efficiency} = \frac{(\text{hp} * 0.746)}{(\text{FLA} * \text{Volts} * \text{PF} * \sqrt{3})}$$

kW saved = (Amps * Volts * PF * $\sqrt{3}$) * (1/existing motor eff. - 1/new motor eff.)

kWh saved per year = (kW saved * hours per year operation)

where:

hp = Nameplate horsepower of existing motor
0.746 = kW/hp
FLA = Nameplate full load amps
Amps = Measured amps of existing motor
Volts = Measured volts of existing motor
PF = Measured power factor of existing motor
$\sqrt{3}$ = Conversion for three phase power
New motor efficiency = from manufacturers' data

Basis for Analysis:
The savings for this ECO were calculated using the hours of motor operation, the existing motor efficiency, and the new motor efficiency. A spreadsheet was used to set up the appropriate formulas.

Results:

Annual Electricity Savings (kWh):	42,400
Peak Electrical Demand Savings (kW):	28
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$1,181
Analysis Period:	25 Years
Estimated Construction Cost:	$58,343
Simple Payback:	47 Years
Savings-to-Investment Ratio (SIR):	0.2

Recommendations:
Do not implement. The government should install high-efficiency motors any time the existing motors require replacement for other reasons.

CENTRAL PLANT 5900 ECO 7.
INSTRUMENTATION TO ESTABLISH BOILER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the boiler.

Boiler plant operators start and stop individual boilers based on their estimate of the daily weather and the HTHW return temperature. This estimate occurs periodically during the day.

Installing instrumentation to establish the required heating capacity and the relevant controls allows minimizing the amount of time extra boilers are operated unnecessarily, thus lowering standby losses. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
Based on field survey observations and interviews with boiler operators, the boilers are operated at least 30 days more per year than the load requires. Running extra boilers has the effect of increasing standby losses.

The energy saved by this ECO is the energy lost by the boiler in standby for 30 days per year.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	161
Total Annual Utility Cost Savings:	$470
Analysis Period:	15 Years
Estimated Construction Cost:	$5,377
Simple Payback:	31 Years
Savings-to-Investment Ratio (SIR):	0.6

Recommendations: Do not implement.

CENTRAL PLANT 5900 ECO 8.
OPTIMIZE BOILER OPERATION

Premise:
This ECO proposes to optimize boiler operation by maximizing use of higher efficiency boilers. The boilers in use operate with system efficiencies ranging from 71% to 81%. The boilers with the lowest efficiencies operate a majority of the heating season hours, while higher efficiency boilers remain idle. Resequencing the higher efficiency boilers to operate more hours will save energy.

Basis for Analysis:
The PC-CUBE energy simulation was used to analyze this ECO. The boiler sequence is changed from the baseline sequence to operate boilers from the most efficient first, to the least efficient last. The energy saved by this ECO is the difference between the baseline and the ECO computer simulation.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	6,157
Total Annual Utility Cost Savings:	$17,978
Analysis Period:	15 Years
Estimated Construction Cost:	$48,257
Simple Payback:	3.0 Years
Savings-to-Investment Ratio (SIR):	4.3

Recommendations: Implement.

CENTRAL PLANT 5900 ECO 9.
IMPROVE BOILER EFFICIENCY

Premise:
This ECO proposes to improve boiler efficiency by renovating boilers, associated equipment, and controls to reduce energy use. Based on combustion efficiency testing and field survey observations, the system efficiencies of the boilers range from 71% to 81%. Overhauling the two worst boilers, which have efficiencies of 71% and 73%, and the associated controls, will increase system efficiencies and save energy.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. As losses from the boilers are reduced, the maximum output of the boiler increases. Because the boilers cannot be renovated to 100% of the design capacity, maximum boiler outputs were increased to within 1% to 2% of the maximum outputs based on rated input to the boilers.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	7,241
Total Annual Utility Cost Savings:	$21,144
Analysis Period:	15 Years
Estimated Construction Cost:	$12,685
Simple Payback:	0.6 Years
Savings-to-Investment Ratio (SIR):	20

Recommendations: Implement.

CENTRAL PLANT 5900 ECO 10.
INSTALL COMBUSTION CONTROLS

Premise:
This ECO proposes to install combustion controls to optimize the fuel-to-air ratio, increasing combustion efficiency and saving energy.

Based on combustion efficiency tests conducted during field surveys, boilers had excessive O_2 in the flue gas. This excessive O_2 transports more heat than necessary out of the boiler, decreasing efficiency and therefore the maximum useful output of a boiler.

Regular testing, by manual or automatic means, enables boiler operators to adjust the fuel-to-air ratio, thereby increasing boiler efficiency.

Depending on the level of energy savings, costs are estimated for manual or automatic testing equipment and controls.

Basis of Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Boiler efficiency inputs were adjusted to increase the maximum useful output of the boilers for a given fuel input. The energy savings of this ECO is the difference between the baseline and the ECO energy simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	3,182
Total Annual Utility Cost Savings:	$9,291
Analysis Period:	15 Years
Estimated Construction Cost:	$44,010
Simple Payback:	8.3 Years
Savings-to-Investment Ratio (SIR):	1.8

Recommendations: Implement.

CENTRAL PLANT 5900 ECO 11.
INSTALL HIGH EFFICIENCY BURNERS

Premise:
All burners require excess air to ensure complete fuel combustion. The excess air represents a loss because the boiler uses energy to heat it, and it is emitted hot with the flue gas. Low excess air burners meeting environmental criteria minimize this type of loss. Combustion air requirements for low excess air burners vary with the firing rates; for low firing rates, excess air must be increased. The percentage of increase varies substantially with the burner manufacturer. A burner that has relatively flat excess air requirements at low firing rates will reduce energy requirements.

Basis for Analysis:
EMC contacted manufacturers of numerous burner representatives; however, it was not possible to locate a burner with a capacity small enough to match these boilers. This ECO is thus not applicable for this central plant.

Results: N/A

Recommendation: N/A

CENTRAL PLANT 5900 ECO 12.
INSTALL STACK ECONOMIZER OR AIR PREHEATER

Premise:
This ECO proposes to install stack economizers or air preheaters to recover heat from the boiler stack and thereby save energy. The boiler stack temperatures are very high on boilers 1 and 2, causing significant heat loss. This ECO analyzes the economic feasibility of installing stack economizers to preheat feedwater to the boiler.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Based on published data, a 40°F rise in combustion air temperature decreases combustion efficiency by approximately 1%. The minimum stack temperature was estimated to be approximately 350°F. The existing stack temperatures are 640°F on boiler 1 and 630°F on boiler 2. A 7% increase in efficiency would be possible for boiler 1 and 2. The energy saved by this ECO is the difference between the baseline and the ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	6,389
Total Annual Utility Cost Savings:	$18,656
Analysis Period:	25 Years
Estimated Construction Cost:	$140,396
Simple Payback:	7 Years
Savings-to-Investment Ratio (SIR):	2.4

Recommendations: Implement.

CENTRAL PLANT 5900 ECO 13.
VARIABLE SPEED PUMPING

Premise:
This ECO proposes to use variable speed pumping for the chilled water distribution system from Central Plant 5900 to the five barracks connected to the plant.

Currently the central plant operators bring chillers on and off as they perceive the load on the plant. In the buildings connected to the central plant, the HVAC equipment uses two-way valves to control cooling. Currently, the plant is designed to control flow by modulating a bypass valve at the central plant to maintain a constant differential pressure at the main headers at the central plant. This is done to maintain the flow through the pumps as the two-way valves close, increasing the supply header pressure. The result is the chilled water pumps have a constant flow. Figure 4-1 on page 4-116 is a simplified diagram of the existing chilled water piping.

Pumping energy can be conserved if the plant is converted to a plant and distribution chilled water loop configuration, whereby the plant loop through the chillers is configured to maintain a constant flow, and the distribution loop is configured to allow for variable flow as required to meet building loads. A differential pressure (DP) transmitter mounted across an HVAC coil and valve, in the building farthest from the central plant, would provide the control signal through the EMCS. The control signal would be integrated with flow meters at the plant, to allow the EMCS to sequence the speed of the pumps, vary the correct number of chillers to have on line, and other associated equipment. Figure 4-2 on page 4-117 indicates the proposed modifications for this ECO.

The pumps in the plant would be converted as follows:

- Replace current chilled water pumps with new pumps capable of pumping the flow and head of the chillers and plant chilled water loop.
- Install new chilled water pumps with variable speed drives, controlled by a DP transmitter in Building 5970, across an HVAC coil and valve, through the EMCS.
- Install new flow meter in the distribution line to determine the central plant load to sequence the chillers.

(Continued)

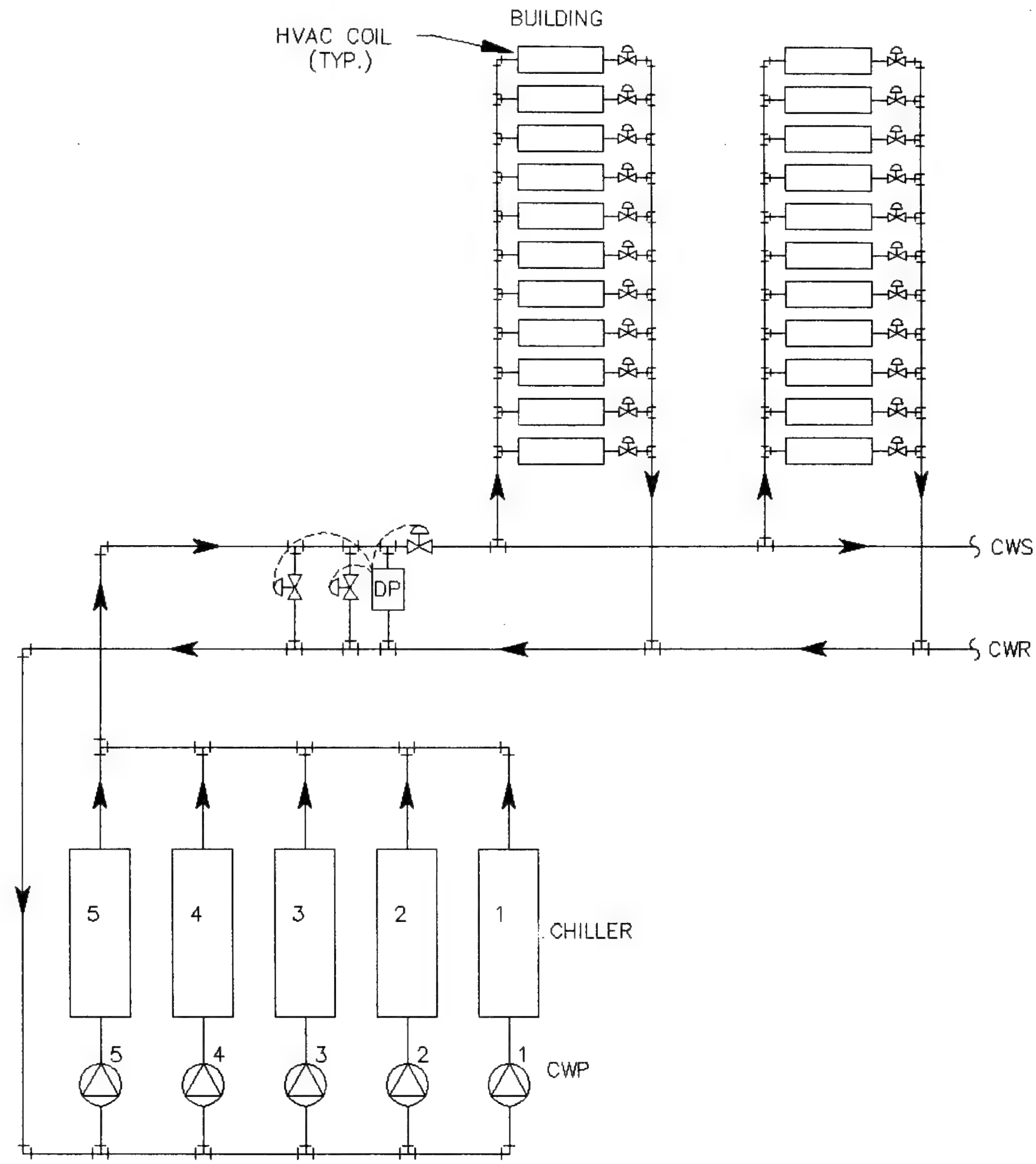
CENTRAL PLANT 5900 ECO 13. (Continued)
VARIABLE SPEED PUMPING

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO, along with calculations of the variable speed pumping energy requirements. The electrical characteristics of the chilled water pumping were changed for each chiller. The variable speed pumping energy was calculated based on the flows and pressure drops at part loads through the distribution system. The energy saved by this ECO is the difference between the baseline and the ECO simulation plus the energy calculated for the variable speed pumping.

Results:

Annual Electricity Savings (kWh):	203,000
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$2,781
Analysis Period:	25 Years
Estimated Construction Cost:	$157,969
Simple Payback:	547 Years
Savings-to-Investment Ratio (SIR):	0.02

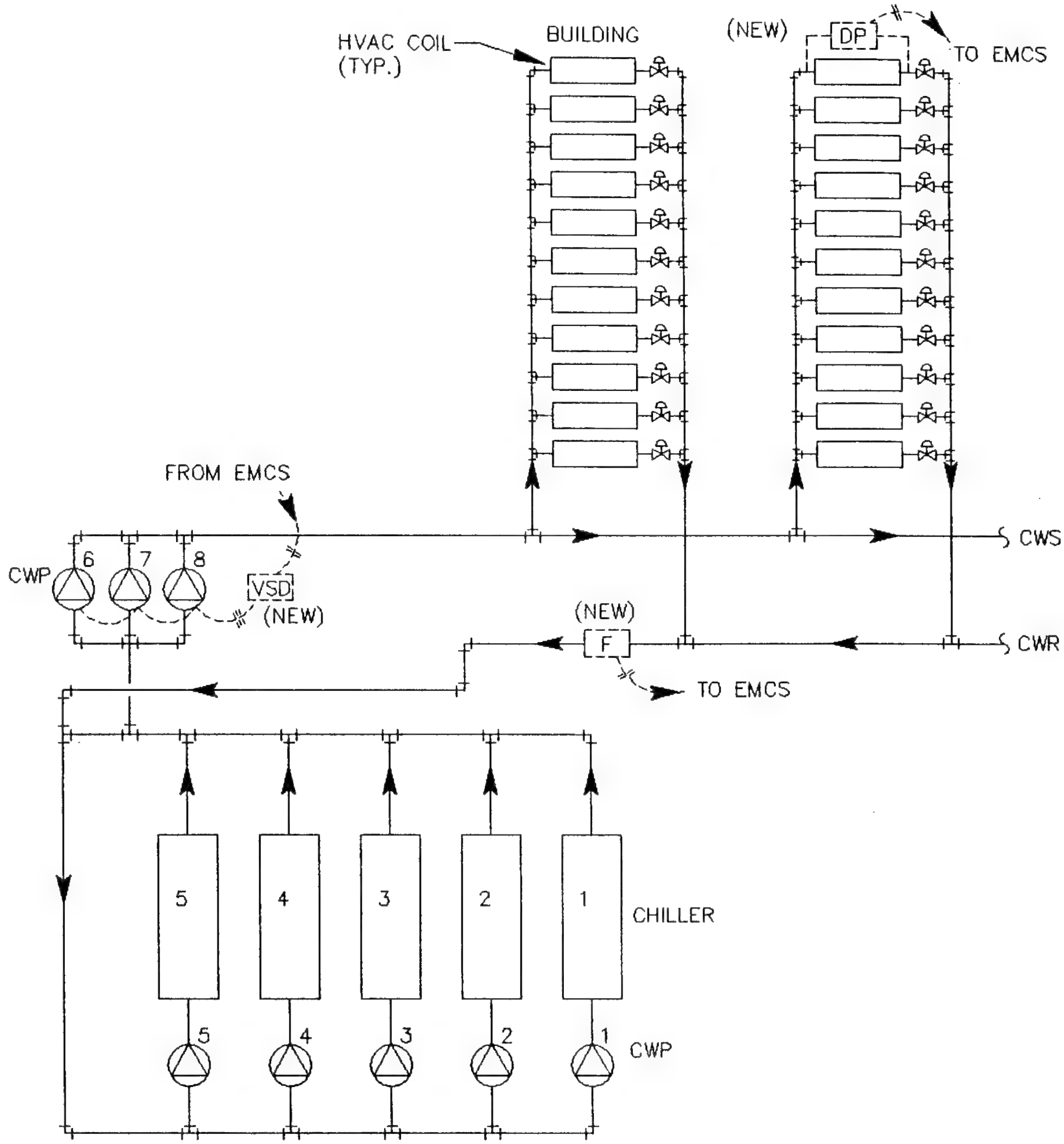
Recommendations: Do not implement.



EXISTING CENTRAL PLANT 5900

CHILLER 1, 2, 3, 5	400 TON EACH
CWP 1, 2, 3, 5	700 GPM @ 190' TDH
CHILLER 4	450 TON
CWP 4	890 GPM @ 190' TDH

FIGURE 4-1, EXISTING CHILLED WATER PIPING



VARIABLE SPEED PUMPING, CENTRAL PLANT 5900

CHILLER 1, 2, 3, 5	400 TON EACH (EXISTING)
CWP 1, 2, 3, 5	700 GPM @ 30' TDH (NEW)
CHILLER 4	450 TON (EXISTING)
CWP 4	890 GPM @ 30' TDH (NEW)
CWP 6, 7, 8	1230 GPM EACH @ 160' TDH (NEW VARIABLE SPEED)

FIGURE 4-2, ECO MODIFICATIONS

4.10 CENTRAL PLANT 6003 EVALUATION

4.10.1 Baseline Energy Usage

Using the PC-CUBE program, Central Plant 6003 was evaluated to determine the baseline energy usage as the plant is currently operated. The baseline calculation considered heating and cooling loads, DHW loads, distribution losses, and Central Plant efficiencies.

The central plant operating procedures taken into account for the baseline calculation include:

- Chillers 2 and 3 (450 tons each) are operated in the summer months.
- Chiller 1 (400 tons) is not used.
- Boilers 1 and 2 are operated in the winter months.
- Boiler 3 is operated in the summer to serve the DHW loads.

The study results indicate the two 450 ton chillers would operate a significant number of hours at 11% to 30% loading. The boiler loads indicate a maximum loading for the first boilers in the winter, with the second boiler loads spread evenly over the load ranges. During the summer, the majority of operating hours for boiler 1 are at 21% to 30% loading.

The estimated annual baseline energy consumption and demand for chillers in Central Plant 6003 are:

- Total electrical consumption, 976,518 kWh.
- Peak electrical demand, 417 kW.

The estimated annual baseline energy consumption for boilers in Central Plant 6003 is:

- Total natural gas consumption, 71,623 MMBtu.

4.10.2 ECO Evaluation

CENTRAL PLANT 6003 ECO 1.
INSTALL INSTRUMENTATION TO ESTABLISH CHILLER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the chiller plant.

Chiller plant operators start and stop individual chillers based on their estimate of the daily weather and the chilled water return temperature. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the actual cooling load minimizes the amount of time extra chillers are operated unnecessarily. The energy savings result from:

- The difference in operating efficiency of the chillers operating at lower load than would be the case if they were more fully loaded.

- The difference in operating only the pumps and cooling towers required for the number of chillers to meet the load.

Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The chiller sequence of operation was changed from the sequence used in the baseline to a sequence in which chiller 1 is on until its rated capacity is reached, then chiller 2 is started and picks up the load in excess of the rated capacity of the first chiller.

The energy saved by this ECO is the difference between the baseline and the ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	215,000
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$2,946
Analysis Period:	15 Years
Estimated Construction Cost:	$5,620
Simple Payback:	1.7 Years
Savings-to-Investment Ratio (SIR):	5.3

Recommendation: Implement.

CENTRAL PLANT 6003 ECO 2.
OPTIMIZE CHILLER OPERATION

Premise:
This ECO proposes to optimize chiller sequence of operation.

Because both chillers operate at the same efficiency and are approximately equal in capacity, negligible savings are possible by changing the sequence of operation. This ECO is thus not applicable to Central Plant 6003.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 6003 ECO 3.
INCREASE CHILLER EFFICIENCY

Premise:
This ECO proposes to repair the chiller to obtain a higher efficiency.

Chiller 1 was not operating at all, and chiller 3 was not operating correctly when surveyed (see Section 2.0). Based on the test data, chillers 2 and 3 operate with efficiencies of roughly 0.64 kW per ton. Because these chillers are operating with good efficiencies, this ECO is not applicable to Central Plant 6003. However, repairs still should be made to assure the chillers are operating properly.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 6003 ECO 4.
INSTALL ICE STORAGE COOLING SYSTEM

Premise:
This ECO proposes to install an ice storage cooling system to reduce peak air conditioning electrical demand (load shifting) and cost.

The primary advantage of an ice storage cooling system is the ability to use lower time-of-day electricity rates and off-peak demand rates to produce ice which can be used instead of chillers to provide cooling for HVAC equipment during times of peak electrical use. Fort Sill does not have this type of rate structure; however, if the overall peak electrical demand can be reduced by shutting off chillers during peak periods, demand charges can be reduced for the whole year.

Basis for Analysis:
The savings of this ECO were calculated, based on the following assumptions.

- A reduction in chiller use of four hours per day is sufficient to reduce peak electrical demand.
- The reduction in demand will occur simultaneously with the overall base electrical demand.
- The auxiliary electrical loads imposed by the ice storage system offset the reduction in chiller auxiliary electrical use.
- The performance penalty due to the chillers producing ice instead of water at normal chilled water temperatures was not taken into consideration (best case scenario).
- The electrical demand savings are $1.787 per kW.

Cost and savings calculations are shown below:

Cost
= Tons capacity x hours per day x $60 per ton-hour
= 850 Tons x 4 hours per day x $60 per ton-hour
= $204,000

(Continued)

CENTRAL PLANT 6003 ECO 4. (Continued)
INSTALL ICE STORAGE SYSTEM

Annual Savings
= Tons capacity x kW per ton x $1.787 per kW-month x 12 months per year
= 850 Tons x 0.64 kW per ton x $1.787 per kW-month x 12 months per year
= $11,666

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	544
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$11,666
Analysis Period:	25 Years
Estimated Construction Cost:	$204,000
Simple Payback:	17.5 Years
Savings-to-Investment Ratio (SIR):	0.7

Recommendation: Do not implement.

CENTRAL PLANT 6003 ECO 5.
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Premise:
This ECO evaluates the use of two-speed fans and variable-speed fans as an alternative to save energy used by the cooling tower. A cooling tower fan drive is built to supply enough air to cool the water to a specified range, when the air is at the design WB. When the air has a lower WB, less air volume is required to do the same job. Since cooling towers must perform even at the worst conditions, and since actual conditions are better than the worst case 98% of the time, the air flow, and therefore the horsepower, required is much less than is built into the cooling tower.

Basically, the more water (and heat) to cool, the more air required to cool it. Also, the lower the inlet air WB to the cooling tower (the lower the inlet air heat content), the less air flow required to cool the water.

In some multicell mechanical-draft cooling towers, the isolation of individual cell air streams is ineffective because of one or more of the following:

- Partitions are missing or in need of repair.
- Partitions are incomplete or the water level is too low.

This condition results in temperature control problems. When one fan of a multicell tower is off, and another cell is running at half or full speed, a substantial amount of air comes from the cells which are off. The air bypasses the wetted fill, causing the fan to operate longer, hence reducing cooling tower efficiency. This problem can be corrected by the use of variable-speed fans. At thermal conditions less than design, all fans can be operated at the precise speed required to maintain the condenser water temperature. Thus, the cooling air will flow through the fill, even without partitions, and no more power will be expended than is necessary.

Some existing cooling towers at Fort Sill presently take advantage of two-speed fan control, but none take advantage of variable-speed cooling tower control.

Basis for Analysis:
The savings for this ECO were calculated with the following basis for analysis:

- The heat released by water must equal the heat absorbed by air in order for the cooling tower to function.

- An approximation is made from computer energy simulation runs of the hourly profile of building cooling loads.

(Continued)

CENTRAL PLANT 6003 ECO 5. (Continued)
TWO-SPEED AND VARIABLE-SPEED COOLING TOWER FANS

Basis for Analysis: (Continued)

- Knowing the performance of the tower and the ambient wet bulb temperature, the percent of design capacity can be calculated for each part load condition and wet bulb temperature.

- The number of stages of control for the two-speed fan retrofit was calculated based on the number of existing tower fans.

- Brake horsepower of the fan varies as the cube of the air flow. The difference in energy was calculated by taking into account the efficiency of the motor and variable-speed drive.

- The cost for two-speed control was based on new motors and controls for existing towers.

- The cost for variable-speed control was based on new variable-frequency, variable-speed drive retrofit to existing motors.

Results:

5(A), Two-Speed Fan Retrofit:

Annual Electricity Savings (kWh):	25,818
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$354
Analysis Period:	25 Years
Estimated Construction Cost:	$11,002
Simple Payback:	29.6 Years
Savings-to-Investment Ratio (SIR):	0.4

5(B), Variable-speed Retrofit:

Annual Electricity Savings (kWh):	31,025
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$425
Annual Maintenance Cost:	$570
Net Annual Savings:	-$145
Analysis Period:	25 Years
Estimated Construction Cost:	$10,021
Simple Payback:	N/A Years (Negative Savings)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation:

Two-speed fan control: Do not implement.

CENTRAL PLANT 6003 ECO 6.
INSTALL HIGH-EFFICIENCY MOTORS FOR CHILLED WATER PUMPS

Premise:
This ECO proposes to replace existing motors with high-efficiency motors to save electrical energy. The savings from installing high-efficiency motors are given by:

$$\text{Existing motor efficiency} = \frac{(hp * 0.746)}{(FLA * Volts * PF * \sqrt{3})}$$

kW saved = (Amps * Volts * PF * $\sqrt{3}$) * (1/existing motor eff. - 1/new motor eff.)

kWh saved per year = (kW saved * hours per year operation)

where:

hp = Nameplate horsepower of existing motor
0.746 = kW/hp
FLA = Nameplate full load maps
Amps = Measured amps of existing motor
Volts = Measured volts of existing motor
PF = Measured power factor of existing motor
$\sqrt{3}$ = Conversion for three phase power
New motor efficiency = from manufacturers' data

Results:

Annual Electricity Savings (kWh):	25,861
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$611
Analysis Period:	25 Years
Estimated Construction Cost:	$23,185
Simple Payback:	36.1 Years
Savings-to-Investment Ratio (SIR):	0.3

Recommendation:
Do not implement. The government should install high-efficiency motors any time the existing motors require replacement for other reasons.

CENTRAL PLANT 6003 ECO 7.
INSTRUMENTATION TO ESTABLISH BOILER LOAD

Premise:
This ECO proposes to install BTU metering to establish the actual load on the boiler.

Boiler plant operators start and stop individual boilers based on their estimate of the daily weather. This estimate occurs once in the morning and once in the evening.

Installing instrumentation to establish the required heating capacity and the relevant controls allows minimizing the amount of time extra boilers are operated unnecessarily, thus lowering standby losses. Operators would be required to monitor the measured actual load on the plant and bring equipment on and off manually.

Basis for Analysis:
Based on field survey observations and interviews with boiler operators, the boilers are operated at least 30 days more per year than the load requires. Running extra boilers has the effect of increasing standby losses.

The energy saved by this ECO is the energy lost by the boiler in standby for 30 days per year.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	67
Total Annual Utility Cost Savings:	$196
Analysis Period:	15 Years
Estimated Construction Cost:	$4,482
Simple Payback:	N/A Years (Savings less than cost)
Savings-to-Investment Ratio (SIR):	N/A

Recommendation: Do not implement.

CENTRAL PLANT 6003 ECO 8.
OPTIMIZE BOILER OPERATION

Premise:
This ECO proposes to optimize boiler operation by maximizing use of higher efficiency boilers. The two boilers in use have system efficiencies ranging from 80% to 82%. Because the boilers are sequencing to operate the most efficient first to the least efficient last, there is no benefit in resequencing boiler operation. This ECO is thus not applicable to Central Plant 6003.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 6003 ECO 9.
IMPROVE BOILER EFFICIENCY

Premise:
This ECO proposes to improve boiler efficiency by renovating boilers, associated equipment, and controls to reduce energy use. Based on combustion efficiency testing and field survey observations, the system efficiencies of the boilers range from 80% to 82%. Because the boilers operate near optimal system efficiency, little can be done to increase boiler efficiency.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 6003 ECO 10.
INSTALL COMBUSTION CONTROLS

Premise:
This ECO proposes to install combustion controls to optimize the fuel-to-air ratio, increasing combustion efficiency and saving energy.

Based on combustion efficiency tests conducted during field surveys, boilers had excessive O_2 in the flue gas. This excessive O_2 transports more heat than necessary out of the boiler, decreasing efficiency and therefore the maximum useful output of a boiler.

Regular testing, by manual or automatic means, enables boiler operators to adjust the fuel-to-air ratio, thereby increasing boiler efficiency.

Depending on the level of energy savings, costs are estimated for manual or automatic testing equipment and controls.

Basis of Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. Boiler efficiency inputs were adjusted to increase the maximum useful output of the boilers for a given fuel input. The energy savings of this ECO is the difference between the baseline and the ECO energy simulations.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	450
Total Annual Utility Cost Savings:	$1,314
Analysis Period:	15 Years
Estimated Construction Cost:	$20,083
Simple Payback:	150 Years
Savings-to-Investment Ratio (SIR):	0.3

Recommendation: Do not implement.

CENTRAL PLANT 6003 ECO 11.
INSTALL HIGH EFFICIENCY BURNERS

Premise:
All burners require excess air to ensure complete fuel combustion. The excess air represents a loss because the boiler uses energy to heat it, and it is emitted hot with the flue gas. Low excess air burners meeting environmental criteria minimize this type of loss. Combustion air requirements for low excess air burners vary with the firing rates; for low firing rates, excess air must be increased. The percentage of increase varies substantially with the burner manufacturer. A burner that has relatively flat excess air requirements at low firing rates will reduce energy requirements.

Basis for Analysis:
EMC contacted manufacturers of numerous burner representatives; however, it was not possible to locate a burner with a capacity small enough to match these boilers. This ECO is thus not applicable for this central plant.

Results: N/A

Recommendation: N/A

CENTRAL PLANT 6003 ECO 12.
INSTALL STACK ECONOMIZER OR AIR PREHEATER

Premise:
This ECO proposes to install stack economizers or air preheaters to recover heat from the boiler stack and thereby save energy. Many of the boiler stack temperatures are high enough to allow significant heat loss.

Based on professional engineering judgement, field survey observations, and published boiler data, economizers are not applicable to any of the boilers in Building 6003, because inadequate boiler heat transfer surface is not indicated, nor do high stack temperatures exist. This ECO is thus not applicable to Central Plant 6003.

Basis for Analysis: N/A

Results: N/A

Recommendation: N/A

CENTRAL PLANT 6003 ECO 15.
COGENERATION WITH NATURAL GAS TURBINE

Premise:
An investigation was conducted at Central Plant 6003 to determine if cogeneration using a natural gas turbine would be economically feasible. Cogeneration, in this case, can be defined as generating electricity on-site with natural gas turbine engines and reclaiming heat from those engines to produce steam for DHW.

The primary product of the cogeneration would be electricity, to be used to supply the existing chillers and associated pumps and cooling towers. The heat recovered from the natural gas turbine would be used for the summer heating loads, including DHW and distribution losses.

Central Plant 6003 was selected for the cogeneration analysis because of a number of factors:

- Summer chiller electrical loads.
- Summer heating loads.
- Electrical distribution which could be easily switched from on-site to utility power.
- Sufficient area to expand plant for additional equipment.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this ECO. The performance curve for a 1,100 kW natural gas turbine was input to handle 100% of the electrical demand for Central Plant 6003. The recoverable heat from the gas turbine was used to meet the heating load of the central plant. The energy saved by this ECO is the difference between the baseline and ECO computer simulations.

Results:

Annual Electricity Savings (kWh):	977,000
Peak Electrical Demand Savings (kW):	417
Annual Natural Gas Savings (MMBtu):	-49,603
Total Annual Utility Cost Savings:	-$131,456
Analysis Period:	N/A Years
Estimated Construction Cost:	N/A $
Simple Payback:	N/A Years
Savings-to-Investment Ratio (SIR):	N/A

The cost of electrical energy and demand from the utility are too low in this case to offset the inefficiencies of turbine engines. The heating load in this case was not large enough to utilize the amount of waste heat generated.

Recommendation: Do not implement.

SECTION 5.0

SPECIAL CONSIDERATIONS AND PREVIOUS STUDY PLANT EVALUATIONS

5.1 GENERAL

A number of central plants identified in the SOW for this project have been reviewed under previous Energy Engineering Analysis Program (EEAP) studies. The reports provided to EMC include, "Phase III, Master Planning and Analysis of Heating and Cooling Central Plant Distribution Systems For Fort Sill, Oklahoma," by Carnahan-Thompson-Delano (CTD), September 1980; and "Energy Consumption and Requirement Report," CTD, 1980. Those plants and studies specifically identified in the SOW were reviewed and updated, and the results are included in the following sections.

Section 5.12 of this submittal briefly discusses the concept of third-party financing (TPF) as it relates to central plants. This was not a specified requirement of the SOW for this contract, but may be an important future consideration for Fort Sill if central plant replacement and upgrades are needed.

5.2 CENTRAL PLANT 730, CAPACITY TO SERVE ADDITIONAL BUILDINGS

The rating of the equipment in Central Plant 730 was compared with the connected load to determine if there is sufficient capacity to serve additional buildings. The results of the CTD master planning study are identified in Table 5-1 on page 5-2. The chiller capacity was revised to indicate the chiller capacity of currently installed equipment. The study indicates there are 371 tons of additional cooling capacity and no additional heating capacity.

The current operators were interviewed, and from an operational standpoint, the chillers appear to have excess capacity. EMC understands the plant operators normally use only the main 800 ton chiller during most of the summer cooling season (see Central Plant 730 description, Section 2.2.1). Potentially, therefore, 600 tons of excess cooling are available.

No labor, energy, or capital cost savings are identified in the CTD master planning study regarding this evaluation.

TABLE 5-1
CENTRAL PLANT 730 - LOAD SCHEDULE

TOTAL CONNECTED LOAD	HEATING (MMBtuh)	COOLING (Tons)
Building 730	5.793	570
Building 840	3.757	128
Building 700	4.220	362
Building 707	2.215	198
Total Connected Load	**15.985**	**1258**
Diversity, Heating 75%	12.000	-
Diversity, Cooling 85%	-	1069
Estimated Installed Capacity	**11.055**	**1440**
Estimated Surplus Capacity	**0**	**371**

5.3 CENTRAL PLANTS 5676 AND 5678, FEASIBILITY OF CONNECTING PLANTS

The feasibility of connecting Central Plant 5676 and Central Plant 5678 was not reviewed in the previous studies provided to EMC by Fort Sill. See Sections 2.2.6 and 2.2.7, on pages 2-26 and 2-30, respectively, for descriptions of the existing equipment associated with these two central plants. The following engineering judgments should be considered regarding this project:

- The two buildings are close in proximity, which allows for an easy connection of the central plants.
- The daily load requirements of the two plants are similar because both buildings are used as visitor officer quarters. Thus, plant operating times are the same in each case.
- In central heating plants, connecting buildings with individual plants reduces the standby losses for the boilers. Connecting plants will keep the load up on fewer individual boilers, thus lowering standby losses. Standby savings will be achieved by connecting the two plants. The standby losses are approximately 1% of capacity at full load.
- In many cases, a major reason to connect plants is to save manpower. Where plants are attended 24 hours a day, 7 days a week, connecting the plants will reduce the required manpower by half. This is not the case, however, with Plants 5676 and 5678, which are only checked periodically.

- If the plants are connected, additional distribution losses will occur from heat transfer through piping installed between the two buildings.

- If the plants are connected, additional pumping energy will be required for moving chilled water and hot water between buildings.

Because there are no labor savings, and because the energy savings from standby losses are offset by increased pumping energy and distribution losses, connecting the two plants does not provide Fort Sill with significantly increased opportunities. If equipment in both buildings requires replacement because of age, condition, or other related factors, potential cost savings exist in building a new plant serving both buildings, instead of installing two new sets of equipment. A more complete investigation into the condition, age, and expected life of the existing equipment, along with a detailed cost estimate, is necessary to complete this feasibility evaluation.

5.4 CENTRAL PLANT 3442, OPPORTUNITY FOR CENTRAL HEATING PLANT

The feasibility of building a central heating plant in the 3400 area, similar to Central Plant 3442 which now houses chillers for central chilled water, was evaluated in the CTD master planning study. Currently, the barracks in this area are served by two individual boilers, with associated gas, water, and sewer services, and space. The boilers appear to be old and nearing the need for replacement. Exterior wall insulation has been added, and window area has been reduced. This project was submitted for construction under Project No. B408-T497, "Central Heating Plant Addition (ECIP)," but it never received funding. EMC understands the project is currently included as part of another project for the 3400 area barracks upgrade.

The project was evaluated in this Prefinal Submittal as a comparison between replacing local hot water boilers in each barracks versus constructing a central heating plant, see Section 8.2.5

5.5 CENTRAL PLANT 914, ADD CENTRAL HEATING PLANT

Buildings 900, 912, 913, and 914 are currently served by a boiler in each of the individual buildings; however, these buildings are connected to a new central chiller plant in Building 914. The feasibility of connecting these buildings and serving them from a central location was not reviewed in the previous studies provided to EMC by Fort Sill. See Section 2.2.2 for a description of the existing central plant equipment associated with these buildings.

As outlined in Section 5.3 on pages 5-2 and 5-3, the main reasons for and against a central plant include:

- Reasons for building a central heating plant:

  - Lower standby losses.

- Less maintenance to attend boilers.
- Potentially lower capital investment to build a new, large replacement plant.

- Reasons against building a central heating plant:

  - Additional distribution losses.
  - Additional pumping energy.

Because there are no labor savings, and the energy savings from standby losses are offset by increased pumping energy and distribution losses, connecting the buildings with a central plant does not provide Fort Sill with substantially increased opportunities. If equipment in all buildings requires replacement because of age, condition, or other related factors, potential cost savings exist for building a new large plant serving all buildings, instead of installing multiple new sets of equipment. A more complete investigation into the condition, age, and expected life of the existing equipment, along with a detailed cost estimate, is required to complete this feasibility evaluation. An additional comparison should be made to determine if a life cycle cost analysis proves high efficiency modular boilers in each building to be the most cost efficient alternative.

This set of buildings was also programmed for inclusion in the 800 area new central plant project (see Section 5.9 on page 5-6).

5.6 CENTRAL PLANT 4701, CHANGE PLANT REQUIREMENTS

Central Plant 4701 was designed to handle the loads and special requirements of the hospital, Building 4700. In a few years, the hospital will be moved to the new facility currently under construction. At that time, Building 4700 is expected to be renovated into office areas. No special requirements are anticipated. The SOW discusses downgrading the system to low pressure steam and using excess capacity elsewhere.

Even with the hospital heating and cooling loads, DHW load, and distribution losses in the plant, the CTD master planning study indicates Central Plant 4701 had 4.737 MMBtuh excess heating capacity and 294 tons of excess cooling capacity. With future modifications to Central Plant 4701, the excess heating capacity, especially DHW and steam process loads, is expected to be still greater.

It is reasonable to consider using this excess capacity to serve additional buildings in the vicinity of Central Plant 4701. The only major (permanent) buildings in the area of this central plant are the medical barracks, Building 4702, and the club house for the golf course, Building 4746.

If the heating capacity of Central Plant 4701 is used to serve buildings elsewhere, the boilers are not likely to be reduced from high pressure to low pressure, because it will be more economical to transport high pressure steam through smaller high pressure piping than through

low pressure piping. However, converting the boilers to medium or LTHW may be economical.

5.7 CENTRAL PLANT 1653, CAPACITY TO SERVE ADDITIONAL BUILDINGS

The rating of the plant equipment in Central Plant 1653 was compared with the connected load to determine if there is sufficient capacity to serve additional buildings. The results of the CTD master planning study are identified in Table 5-2 below. The study indicates 1,470 MMBtuh of additional heating capacity and no additional cooling capacity.

No labor, energy, or capital cost savings are identified in the master planning study regarding this evaluation. This set of buildings is also programmed for inclusion in the 800 area new central plant project (see Section 5.9 on page 5-6).

TABLE 5-2
CENTRAL PLANT 1653 - LOAD SCHEDULE

Total Connected Load	Heating (MMBtuh)	Cooling (Tons)
Building 1606	0.650	35
Building 1653	1.720	83
Total Connected Load	**2.370**	**118**
Estimated Installed Capacity	6.400	117
@ 60% Boiler Output	3.840	-
Estimated Surplus Capacity	**1.470**	**0**

5.8 CENTRAL PLANT 3442, EXPAND CHILLER PLANT TO SERVE BUILDINGS 2470 AND 2471

The chiller in Central Plant 2471 serves the barracks, Buildings 2470 and 2471. Replacement of this chiller with an extension of Central Plant 3442 was proposed. However, it was determined in the Interim Submittal review conference that the chiller serving these barracks had recently been replaced. Therefore, this project does not require further analysis.

5.9 CENTRAL PLANT 800 AREA, NEW CENTRAL PLANT

The CTD studies, which were concluded in 1980, evaluated and recommended a new central energy plant (CEP) in the 800 area to provide heating and cooling to 61 buildings. The proposed project would displace existing central plants in Buildings 445, 462, 730, 913, 1603, and

1653. At the time of the CTD study, the proposed coal-fired plant was scheduled for FY82 at an estimated cost of $9.7 million. Heating and cooling was to be distributed to 60 buildings through new underground distribution piping. The CEP and distribution system were never constructed. Table 5-3 on the following page provides the heating and cooling capacities identified in the CTD master planning study for the CEP in the 800 area.

A long-range requirement for 94.531 MMBtuh heating capacity and 4,512 tons of cooling capacity was estimated. An additional 1,100 ton chiller would be required to handle the extra cooling requirements.

The savings and cost listed for this project in the master planning study include:

- 5,419,000 kWh savings.
- 264,494 kcf natural gas savings.
- -5,962.3 tons of coal savings.
- $816,605 savings (1980).
- $9,748,000 escalated construction cost (1980).
- 11.7 year payback.
- 1.3 SIR.

EMC understands this project was dropped because of its relatively long payback. Fort Sill may wish to consider a TPF project for the CEP in the 800 area (see Section 5.12 on page 5-10).

TABLE 5-3
CENTRAL ENERGY PLANT - 800 AREA

CONNECTED LOADS	HEATING (MMBtuh)	COOLING (TONS)
FY82 Connected Load	105.857	4684
- 75% Diversity	79.393	3513
- 10% Pipe Loss	7.939	0
- New Proposed Plant Heating Loss	.600	0
Total FY82 Estimated Loads	87.932	3513
FY82 Proposed Boiler Capacity		
- Four Coal-fired Boilers (ea.)	25.000	
Total Capacity	100.000	
- Surplus Capacity	12.068	
FY82 Proposed Chiller Capacity		
- One Small Chiller		500
- One Medium Chiller		1100
- One Large Chiller		2000
Total Capacity		3600
- Surplus Capacity		87

5.10 CENTRAL PLANT 5900, REFUSE-DERIVED FUEL BOILERS

As potential modifications, the SOW identifies both the expansion of Central Plant 5900 to additional facilities and the use of refuse-derived fuel (RDF) boilers. A review of the CTD master planning study indicates all the facilities proposed in the 1980 study were added to the central plant. Additional buildings for this area of Fort Sill are proposed in the master plan, and it is likely these buildings will be added to the central plant distribution system in the future.

This project was submitted for construction under Project No. B408-T498, "Refuse Derived Fuel, 5900 C.E.P.," but it never received funding. An addition was planned for Central Plant 5900 to house an incinerator boiler to burn RDF and to generate HTHW, thereby offsetting the need for one existing boiler. The action was estimated to reduce annual landfill volume by 72%. The documentation for the RDF boiler plant provides the following description:

- Equipment, to include boiler, ram loader, conveyors, controls and accessories, electrical service, loaders, piping and insulation.

- A 7,110 square foot building addition, to include concrete floors, ash pit, masonry walls, and built-up roof on steel deck.

- RDF will offset energy consumption of existing boilers, reducing fuel oil usage.

- Refuse and ash handling facilities, including additional operators, will be required.

- Landfill requirements will be reduced from 45 tons per day to 12.6 tons per day.

Based on the CTD report estimated costs and savings include:

- Budgetary construction estimate (FY82):

  - Primary facility, $1,077,000.
  - Supporting facility, $324,000.

- Annual recurring energy savings(+), costs(-):

  - Electricity, (-)98,024 kWh per year.
  - Fuel oil, (+)140,400 MMBtu per year.

- Annual recurring non-energy savings(+), costs(-):

  - Materials and repair parts for new boilers, (-) N/A per year.
  - Maintenance labor, (-) N/A per year.
  - Operator labor, (-)$175,200 per year.

Comments regarding the CTD analysis for the RDF central heating plant addition:

- The conceptual engineering calculations seem appropriate for the project.

- The project documentation does not address labor and material required for maintaining the plant.

- Solid waste handling methods should be reviewed and updated.

- Environmental concerns and regulations should be reviewed and updated.

- Natural gas is currently being used as the primary fuel source in place of fuel oil.

It was determined in the Interim Submittal review conference that this project is no longer viable.

Fort Sill may wish to consider a TPF project for the RDF boiler at Central Plant 5900 (see Section 5.12 on page 5-10). Project documentation DD1391 is included in Appendix H.

5.11 CENTRAL PLANT 6003, EXPANSION TO SERVE ADDITIONAL FACILITIES

The rating of the equipment in Central Plant 6003 was compared with the connected load to determine if there is sufficient capacity to serve additional buildings. The results of the CTD master planning study are identified in Table 5-4 on page 5-10. The chiller capacity was revised to indicate chiller capacity of currently installed equipment.

The study indicates 19.03 MMBtuh of additional heating capacity and 535 tons of additional cooling capacity. The current plant operator was interviewed and, from an operational standpoint, it appears the plant has excess capacity (see Central Plant 6003 description, Section 2.2.9 on page 2-38).

According to the 1980 CTD study, six barracks, two administration buildings, and the mess hall are connected to the plant. At the time of the study, future construction to be connected to the plant included:

- Chapel, Building 6080
- Logistics, Building 6130
- Battalion headquarters, Building 6017
- Classroom, Building 6120.

All these facilities were completed and connected to Central Plant 6003. Three major buildings in the 6000 area are not connected to any central plant:

- Dental clinic, Building 6037
- Post exchange, Building 6036
- NCO club, Building 6045.

In the future, when major chiller and boiler equipment in these buildings requires replacement because of age or condition, Fort Sill should consider the cost to purchase replacement equipment versus adding distribution lines from Central Plants 5900 or 6003 to serve these buildings.

No labor, energy, or capital cost savings are identified in the master planning study regarding this evaluation.

TABLE 5-4
CENTRAL PLANT 6003 - LOAD SCHEDULE

TOTAL CONNECTED LOAD	HEATING (MMBtuh)	COOLING (TONS)
Six Barracks	7.997	606
Two Company Admin. Buildings	0.880	37
Mess Hall	2.599	134
Central Plant	0.400	0
Four Additional Buildings	1.921	126
DHW	4.327	0
Total Connected Load	**18.124**	**903**
Diversity Heating 90%	16.31	-
Diversity Cooling 85%	-	767
Estimated Installed Capacity	**35.16**	**1300**
Estimated Surplus Capacity	**19.03**	**535**

5.12 FUNDING OF PLANT MODERNIZATION PROJECTS

Fort Sill has three basic methods of potential funding for the plant modernization work identified:

- Business as usual (BAU)
- Construction using MCP funding
- TPF, the privatization of the central plants proposed.

The concept for the BAU alternative is to renovate existing plants with maximum reliance on O & M funds. Budgetary procedures for MCP funding would allow beneficial occupancy to be targeted for six to seven years; procurement of central plants by TPF methods, however, would allow contractor heating and cooling production to be targeted for two to three years.

Because in many cases funding is limited for plant modernization, TPF may be the best method for accomplishing proposed work. To justify and recommend using TPF for central plant work, a cost comparison would have to evaluate the total life cycle cost for each plant alternative. The analysis would take into account the construction, operating, maintenance, and utility costs over the life of the plant, normally 25 years.

5.13 REQUIREMENTS FOR CHANGES IN CHLOROFLUOROCARBONS

Under the Clean Air Act of 1990, the United States Congress adopted an accelerated phase-out schedule, cutting chlorofluorocarbons (CFC) production to 50% of the 1986 levels by 1995 and to 15% by 1997. This country's CFC production will end by the year 2000. Because most of the chillers at Fort Sill now use CFC-11 or CFC-12, the required changes in CFC production will have a major impact.

Because the HVAC industry has seen the changes coming, reaction to the requirements for changes in refrigerants which will be environmentally safe and less ozone depleting has already occurred. The three main components necessary for phasing out CFC--alternative refrigerants, equipment, and technician training--are in place, and the HVAC industry is making an orderly transition to new technology.

Refrigerant producers now have plants which manufacture CFC alternatives, HCFC 123 and HCFC 134a, in large commercial quantities. Table 5-5 on page 5-12 provides a property comparison of the non-CFC materials. Although none of the new refrigerants are drop-in replacements for CFC, they have proven to be more compatible in existing equipment than was originally expected. To facilitate conversions, equipment manufacturers have completed performance modeling and component testing of much existing equipment to ensure modifications will achieve the desired performance. Converting existing equipment to use alternative refrigerants may require changes in motors, lubricants, gaskets, and gears, to achieve required performance.

Equipment servicing time may increase significantly because of the need to ensure leak-free operation. To prevent emissions during equipment servicing, refrigerant storage vessels and evacuation devices may be required; this will enable the refrigerant charge to be pumped down and stored. The Environmental Protection Agency (EPA) is expected to ban intentional venting and require recycling of CFC by 1992. These rules are expected to apply to all refrigerants, including HCFC, by 1995. The most effective way to conserve refrigerants is to eliminate equipment leaks. Proper maintenance and repair can prevent much refrigerant loss. Leaks are most often found in tubing, flanges, O-rings, and connections where components meet. If a system loses 10% or more of its charge within 12 months, it should be repaired.

While HCFC-123 properties are similar to those of CFC-11, the new refrigerant is not as efficient, resulting in a 2% to 5% average reduction in cycle efficiency. HCFC-123 also has greater mass, reducing capacity in existing chillers by an average 10% to 15%.

ASHRAE committees are formulating industry standards for all alternative refrigerants. Du Pont has assigned an acceptable exposure limit (AEL) for HCFC-123 of 100 ppm, which is below the 1,000 ppm normally associated with CFC. Du Pont's Material Safety Data Sheet for HCFC-123 and ASHRAE Standard 55-1989, "Safety Code for Mechanical Refrigeration," outline requirements for preventing workplace exposure beyond this limit. Several devices help ensure safe operation of HCFC-123. They include an air monitor capable of detecting refrigerant in concentrations of 0 ppm to 100 ppm, a suitable alarm which activates below the refrigerant AEL to alert persons inside and outside the machinery room when a leak has occurred, and a local

exhaust and relief ventilation system to route the fumes outdoors and away from all intakes. Du Pont has assigned an AEL of 1000 ppm for HCFC-134a, identical to the AEL of CFC-12; no special monitoring of exhaust equipment is required.

A number of economic factors must be considered in determining whether to purchase new equipment or convert an existing chiller. These factors include:

- Estimated equipment life
- Equipment current performance
- Operating requirements
- Cost of new equipment
- Cost of equipment room modifications
- Maintenance and refrigerant costs
- Utility costs.

The EPA forecasts the cost of CFC-11, which is currently $3.50 to $4 per pound, will rise to $12 per pound by 1999. Thus, a 1,000-pound charge costing around $4,000 today would be $12,000 in 1999. The cost today for HCFC-123 is about double the cost of CFC-11; HCFC-123, however, is trending downward, while CFC-11 is trending upward. Du Pont predicts a pricing crossover will occur sometime in 1992 or 1993.

If a system now operating on CFC has marginal capacity, converting to a new refrigerant may leave it short of capacity or with poor performance. The manufacturers are currently testing and developing performance charts for HCFC conversions. When this information is complete, the government should make a comprehensive evaluation to determine how the new refrigerant will affect capacity and efficiency and what modifications are needed to achieve optimum performance.

TABLE 5-5
REFRIGERANT PROPERTY COMPARISONS

PROPERTY	CFC-11	HCFC-123	CFC-12	HCFC-134a
Boiling Point (°F)	74.9	81.7	-21.6	-15.7
Flammability	None	None	None	None
Toxicity	1000 ppm	100 ppm	1000 ppm	1000 ppm
Ozone Depletion	1.0	0.02	1.0	0.0
Global Warming*	1.0	.02	2.8	0.3

* Calculated; compared to CFC-12, 2.8.

SECTION 6.0

LOW COST OR NO COST ECOs AND OPERATIONAL ACTION ITEMS

6.1 GENERAL

Presented in this section are action items which can be quickly implemented. These actions, noted during the study, are mainly operational items which will affect energy conservation.

6.2 LOW COST OR NO COST ECOs AND OPERATIONAL ACTION ITEMS

Action items which can be quickly implemented were noted from the survey and from the evaluation of equipment. These actions are mainly operational items which will affect energy conservation. Descriptions of these items are included in the following subsections.

All chillers have annual maintenance performed to clean tubes, maintain water treatment, and so forth. Proper maintenance on large chiller systems not only deters unexpected failures, but also ensures significant energy savings through more efficient operations. To help assure proper operation and high efficiency, Fort Sill should develop a maintenance checklist for weekly, monthly, and annual chiller repairs and adjustments.

Observations indicate a detailed check of fuel oil burning devices and safety valves is not included in the State Boiler Inspection. The Government would benefit from boiler inspections of all items. During the course of conducting the site investigation, safety violations were observed.

Many boiler plants have the ability to burn fuel oil as a standby fuel. However, no boiler plants were reported to utilize fuel oil, because fuel oil burning equipment is not regularly put on the line and because fuel oil burning apparatus is not operable. For that reason, boilers were tested using only natural gas fuel.

Only Central Plant 4701 and Central Plant 5900 keep log data; however, the data lacked credibility. Maintaining records of basic pressure, flow, and temperature instrumentation on boilers is recommended. Readings, reviewed monthly by supervisors, should be taken as often as possible (hourly, daily, weekly, and monthly). Any major changes in readings from month to month and year to year should be noted and explained.

According to operators, the fuel-to-air ratios on boilers were set without the use of flue gas analyzers. Linkages on burner controls were not fixed, so the fuel-to-air ratio may be upset by loose nuts, bolts, and so forth. A stack gas reading should be recorded weekly on large central plant boilers, and the fuel-to-air ratio should be set at the beginning of the heating season, and every 90 days thereafter. It is recommended Fort Sill train a single specialized maintenance crew to test and adjust boilers with a flue gas analyzer, rather than having these procedures performed by each central plant operator. To help assure proper operation and

high efficiency, Fort Sill should develop a maintenance checklist for weekly, monthly, and annual boiler repairs and adjustments.

6.2.1 Central Plant 730

Chillers:

Central Plant 730 has three chillers, two 300 tons and one 800 tons. The chillers in Central Plant 730 could be run more efficiently if additional attention is directed at operating the chiller and pumps most suited to fit the estimated load. No instrumentation is present to inform operators of the size of the load currently on the plant. However, by following the basic steps identified below, with the chilled water setpoints described, operators should be able to maintain adequate cooling.

Table 6-1 on page 6-4 is an operational matrix based on load for the chillers, pumps, and cooling towers. The operational steps for chillers in Central Plant 730 are described below:

Low load (0 tons to 300 tons) condition:

- The 300 ton chiller, one main chilled water pump, the small condenser water pump, and the cooling tower should be operated to maintain:

  - Minimum chilled water supply setpoint, 40°F.
  - Chilled water return temperature, 52°F.

- The 300 ton chiller is designed for 600 gpm. One main chilled water pump will deliver 1,300 gpm.

- The chilled water setpoint should be adjusted to maintain the chilled water return temperature at 52°F.

Medium load (300 tons to 600 tons) condition:

- When the chilled water supply temperature on the first 300 ton chiller is 40°F, and the temperature of the return rises above 52°F, the second 300 ton chiller should be brought on line in addition to the first 300 ton chiller.

- Two 300 ton chillers, one main chilled water pump, one large condenser water pump, and the cooling tower should be operated to maintain:

  - Minimum chilled water supply setpoint, 40°F.
  - Chilled water return temperature, 52°F.

- Each 300 ton chiller is designed for 600 gpm. One main chilled water pump will deliver 1,300 gpm.

- The chilled water setpoint should be adjusted to maintain the chilled water return temperature at 52°F.

High load (600 tons to 800 tons) condition:

- When the chilled water supply temperature on the two 300 ton chillers is 40°F, and the temperature of the return rises above 52°F, the 800 ton chiller should be brought on line in place of the two 200 ton chillers.

- The 800 ton chiller, one main chilled water pump, one large condenser water pump, and the cooling tower should be operated to maintain:

  - Minimum chilled water supply setpoint, 38°F.
  - Chilled water return temperature, 53°F.

- The chilled water setpoint should be adjusted to maintain the chilled water return temperature at 53°F.

Peak load (above 800 tons) condition:

- When the chilled water supply temperature on the 800 ton chiller is 38°F, and the temperature of the return rises above 53°F, one 300 ton chiller should be brought on line in addition to the 800 ton chiller.

- The 800 and 300 ton chillers, two main chilled water pumps, one large and one small condenser water pump, and the cooling tower should be operated to maintain:

  - Minimum chilled water supply setpoint, 38°F.
  - Chilled water return temperature, 53°F.

- The chilled water setpoint should be adjusted to maintain the chilled water return temperature at 53°F.

Additional operational action items:

- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as the chiller will tolerate, without surging or going off on safety controls, such as low refrigerant suction pressure, or as low as can be provided under the outdoor air conditions.

- The lower basin of the cooling tower above the two-cell partition should be filled to eliminate cross-flow between cells. If only one fan is running, when the water level is below the partition, air is pulled through the second fan opening, and not through the cooling tower media. As a result, one fan runs longer because the air is not flowing across the condenser water.

TABLE 6-1
CENTRAL PLANT 730 OPERATIONAL MATRIX

EQUIPMENT	LOAD			
	LOW	MEDIUM	HIGH	PEAK
CHILLER - 300 TONS	ON	ON	OFF	ON
CHILLER - 300 TONS	OFF	ON	OFF	OFF
CHILLER - 800 TONS	OFF	OFF	ON	ON
CW PUMP - 1	ON	ON	ON	ON
CW PUMP - 2	OFF	OFF	OFF	ON
CNW PUMP - 1	OFF	ON	ON	ON
CNW PUMP - 2	OFF	OFF	OFF	OFF
CNW PUMP - 3	ON	OFF	OFF	ON
COOLING TOWER	ON	ON	ON	ON
CWS MINIMUM SETPOINT (°F)	40	40	38	38
CWR MAXIMUM SETPOINT (°F)	52	52	53	53

Boilers:

Three of the four boilers in Central Plant 730 operate during the winter to meet heating and DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

Various operating conditions of hot water temperatures and hot water pumping from Central Plant 730 should be tested. To reduce distribution losses, hot water supply temperatures should be maintained at a minimum. To lower pumping requirements, the minimum number of water pumps should be run to meet the heating load.

To maintain the longer boiler life associated with lower boiler temperatures and pressures, operators should also try lowering the boiler steam pressure from 10 psig to less (2 psig to 5 psig).

6.2.2 Central Plant 914

Chillers:

Central Plant 914 has one 400 ton chiller which, although new, is not operating at rated capacity or specified efficiency. (See survey information discussed in Section 2.2.2 on page 2-11 of this submittal.) The measured efficiency was 1.23 kW per ton, versus the design rating of 0.65 kW per ton to 0.7 kW per ton. The pressure drop across the evaporator was much higher than the design; EMC noted a drop of 23 foot head of water, compared to a maximum design of 10 foot head of water. This indicates a potential problem with clogged tubes (fouling). The same problem was experienced with the pressure drop across the condenser; however, this problem is not as severe. For the condenser, EMC measured the pressure drop at 13.8 foot head of water, compared to a design pressure drop of 10 foot head of water. Cleaning the tubes, as well as diagnosing and solving this problem will assure there is adequate capacity for the cooling load, and will also save energy because of higher efficiencies.

Although a microprocessor-based control system is available for this central plant, the chiller controls were set on manual when surveyed.

Recommended operation of the chiller is as follows:

- Maximum chilled water return temperature, 58°F.
- Minimum chilled water supply setpoint, 45°F.
- To maintain the return temperature at 58°F, the microprocessor-based control system should be programmed to reset chilled water supply temperature setpoint.

Additional operational action items:

- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as the chiller will tolerate, without surging or going off on safety controls, such as low refrigerant suction pressure, or as low as can be provided under the outdoor air conditions. To maintain condenser water temperature as low as possible, the microprocessor-based control system should be programmed to reset the condenser water temperature setpoint. When the condenser water temperature approaches the outside wet bulb temperature, the program should determine whether or not to turn off a cooling tower fan. Based on the cooling tower approach to ambient wet bulb conditions, the decision considers whether the kW saved by turning off a fan is greater than the resulting increase in kW of the compressor, resulting from the higher condenser water inlet temperature.
- The lower basin of the cooling tower above the two-cell partition should be filled to eliminate cross-flow between cells. If only one fan is running when the water level is below the partition, air is pulled through the second fan opening, and not through the

cooling tower media. As a result, one fan will run longer because the air is not flowing across the condenser water.

Boilers:

Central Plant 914 has four boilers, three of which operate during the winter to meet the heating load and one which operates year-round to meet DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

Various operating conditions of hot water temperatures and hot water pumping from Central Plant 914 should be tested. To reduce distribution losses, hot water supply temperatures should be maintained at a minimum. To lower pumping requirements, the minimum number of water pumps should be run to meet the heating load.

To maintain the longer boiler life associated with lower boiler temperatures and pressures, operators should also try lowering the boiler steam pressure from 10 psig to less (2 to 5 psig).

Boilers 3 and 4 in Central Plant 914 produce soot during firing, and soot is removed on a regular basis. This is apparently caused by the unsatisfactory arrangement of individual outlets into the common breaching. Another possible cause is the forced draft burner of the boiler nearest the stack, which may create a positive pressure in the breaching, thus eliminating the stack draft from the three atmospheric burners in this central plant. In order to avoid future catastrophe, the root of the upset condition must be corrected, rather than continually removing soot.

6.2.3 Central Plant 2812

Chiller:

Recommended operation of the chiller is as follows:

- Maximum chilled water return temperature, 61°F.
- Minimum chilled water supply setpoint, 40°F.
- The chilled water supply temperature setpoint should be reset manually to maintain the return temperature at 61°F.
- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as the chiller will tolerate, without surging or going off on safety controls, such as low refrigerant suction pressure, or as low as can be provided under the

outdoor air conditions. To maintain as low temperature as possible, the condenser water temperature setpoint should be reset manually.

Boilers:

Central Plant 2812 has three boilers, two of which operate during the winter to meet the heating and DHW loads, and one which operates year-round to provide steam for the mess hall, Building 2811. No master boiler control is present to control staging of the boilers.

Various operating conditions of hot water temperatures and hot water pumping from Central Plant 2812 should be tested. To reduce distribution losses, hot water supply temperatures should be maintained at a minimum. To lower pumping requirements, the minimum number of water pumps should be run to meet the heating load.

To maintain the longer boiler life associated with lower boiler temperatures and pressures, operators should also try lowering the boiler steam pressure from 10 psig to less (2 to 5 psig).

6.2.4 Central Plant 3442

Chillers:

Central Plant 3442 has two 600 ton chillers. Although a microprocessor-based control system is available for this plant, the chiller controls were set on manual when surveyed. The telephone line connecting the central plant microprocessor-based controls with the DEH operator console had been removed.

Fort Sill would benefit if communication command were to reinstall a telephone line to provide remote monitoring of the central plant. In addition, the microprocessor-based control system should be tested and made operational to optimize chiller usage. The chillers in Central Plant 3442 will be run more efficiently if additional attention is directed at those chillers and pumps most suited to fit the estimated load. No instrumentation is present to inform operators of the size of the load currently on the plant. However, by following the basic steps identified below, with the chilled water setpoints described, operators (or microprocessor-based controller) should be able to maintain adequate cooling.

The operational steps for chillers in Central Plant 3442 are described below:

Low load (0 tons to 600 tons) condition:

- One 600 ton chiller, one main chilled water pump, one condenser water pump, and one set of cooling towers should be operated to maintain:

  - Minimum chilled water supply setpoint, 45°F.

- Chilled water return temperature, 60°F.

- The chilled water setpoint should be adjusted (manually or through the automated controls) to maintain the chilled water return temperature at 60°F.

High load (600 tons to 1,200 tons) condition:

- When the chilled water supply temperature is set at 45°F, and the temperature of the return rises above 60°F, the second 600 ton chiller should be brought on line, in addition to the first 600 ton chiller.

- The two 600 ton chillers, two chilled water pumps, two condenser water pumps, and both sets of cooling towers should be operated to maintain:

  - Minimum chilled water supply setpoint, 45°F.
  - Chilled water return temperature, 60°F.

- The chilled water setpoint should be adjusted to maintain the chilled water return temperature at 60°F.

Additional operational action items:

- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as the chiller will tolerate, without surging or going off on safety controls, such as low refrigerant suction pressure, or as low as can be provided under the outdoor air conditions. To maintain a condenser water temperature as low as possible, the microprocessor-based control system should also be programmed to reset the condenser water temperature setpoint to run all the tower fans. When the condenser water temperature approaches the outside wet bulb temperature, the program should determine whether or not to turn off a cooling tower fan. Based on the cooling tower approach to ambient wet bulb conditions, this decision considers whether the kW saved by turning a fan off is greater than the resulting increase in kW of the compressor, resulting from the higher condenser water inlet temperature.

- The lower basin of the cooling tower above the two-cell partition should be filled to eliminate cross-flow between cells. If only one fan is running when the water level is below the partition, air is pulled through the second fan opening, and not through the cooling tower media. As a result, one fan will run longer because the air is not flowing across the condenser water.

- The upper basin on the cooling tower should be cleaned and covered to assure proper flow through the cooling tower media.

- The deposit buildup on the cooling tower media should be cleaned to assure proper cooling tower performance.

6.2.5 Central Plant 4701

Chillers:

Central Plant 4701, which serves the hospital, has two 275 ton chillers. One of the chillers operates at very poor efficiency (1.31 kW per ton), while the other chiller surges. Chiller 1 requires constant refrigeration charging. Diagnosing and solving the problems will assure there is adequate capacity for the cooling load and will also save energy by increasing efficiency.

Because of the critical requirements of the hospital, the operators should continue to operate the chillers as needed to maintain environmental conditions. Based on the efficiency of the two chillers, it is recommended the operators use chiller 2 first. If the hospital operations are moved to the new facility and Building 4700 no longer has critical requirements, the operators should attempt to reset chilled water temperatures to save energy.

Based on the original design drawings for the hospital, the chiller plant was set to operate as follows:

- Maximum chilled water return temperature, 53°F.
- Chilled water supply setpoint, 43°F.
- One chilled water pump and one condenser pump have adequate flow for both chillers.

Additional operational action items:

- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as the chiller will tolerate, without surging or going off on safety controls, such as low refrigerant suction pressure, or as low as can be provided under the outdoor air conditions. To maintain temperature as low as possible, the condenser water temperature setpoint should be reset manually.

Boilers:

Central Plant 4701 has three boilers, two of which operate during the winter to meet the heating and DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

When Building 4700 is converted to an administrative building and there is no need for high pressure steam, the central plant will not require an operator in attendance. Additionally, it is anticipated the steam pressure can be reduced from 100 psig to less than 15 psig, while

continuing to maintain satisfactory capacity with the associated longer life of a boiler operating at lower pressures and temperatures.

6.2.6 Central Plant 5676

Chillers:

Central Plant 5676 has one 170 ton chiller which operates at 1.53 kW per ton, very poor efficiency, when compared to the chiller in Central Plant 5678, which operates at 0.73 kW per ton. Diagnosing and solving the problem with this chiller will assure adequate capacity for the cooling load, and will also save energy because of higher efficiency.

Recommended operation of the chiller is as follows:

- Maximum chilled water return temperature, 52°F.
- Minimum chilled water supply (setpoint) temperature, 44°F.
- Chilled water supply temperature setpoint should be reset manually to maintain the return temperature at 52°F.
- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as the chiller will tolerate, without surging or going off on safety controls, such as low refrigerant suction pressure, or as low as can be provided under the outdoor air conditions. To maintain as low temperature as possible, the condenser water temperature setpoint should be reset manually.

Additional operational action items:

- The flow ports on the upper basin of the cooling tower are clogged with dirt and debris, causing the condenser water to overflow. These ports should be cleaned to assure proper flow across the cooling tower media.

Boilers:

Both boilers in Central Plant 5676 operate during the winter to meet the heating load. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

Various operating conditions of hot water temperatures and hot water pumping from Central Plant 5676 should be tested. To reduce distribution losses, hot water supply temperatures should be maintained at a minimum.

6.2.7 Central Plant 5678

Chiller:

The 190 ton chiller in Central Plant 5678 surged when it was tested above 4° delta T. Diagnosing and solving the problem with this chiller will assure adequate capacity for the cooling load, and also save energy because of higher efficiencies.

Recommended operation of the chiller is as follows:

- Maximum chilled water return temperature, 53°F.
- Minimum chilled water supply setpoint, 45°F.
- Chilled water supply temperature setpoint should be reset manually to maintain the return temperature at 53°F.
- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as the chiller will tolerate, without surging or going off on safety controls, such as low refrigerant suction pressure, or as low as can be provided under the outdoor air conditions. To maintain temperature as low as possible, the condenser water temperature setpoint should be reset manually.

Boilers

The two boilers in Central Plant 5678 operate during the winter to meet heating and DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

Various operating conditions of hot water temperatures and hot water pumping from Central Plant 5678 should be tested. To reduce distribution losses, hot water supply temperatures should be maintained at a minimum.

6.2.8 Central Plant 5900

Chillers:

Central Plant 5900 has five chillers, including four 400 ton units and one 450 ton unit. Efficiencies range from 0.83 kW per ton to 0.94 kW per ton. Only one mechanical problem was noted with the chillers: the cooling tower on chiller 1 seems to be undersized and not able to provide adequate condenser cooling capacity.

The chillers in Central Plant 5900 will be run more efficiently if additional attention is directed at operating the chillers and pumps most suited to fit the estimated load. No instrumentation is present to inform operators of the size of the load currently on the central plant. However, by following the basic steps identified below, with the chilled water setpoints described, operators (or microprocessor-based controller) should be able to maintain adequate cooling.

Recommended operation of the chiller plant is as follows:

Low load (0 tons to 400 tons) condition:

- Chiller 3, its associated chilled water pump, condenser pump, and cooling tower should be operated to maintain:

  - Minimum chilled water supply setpoint, 40°F.
  - Chilled water return temperature, 54°F.

- The chilled water setpoint should be adjusted to maintain the chilled water return temperature at 54°F.

Medium load (400 tons to 800 tons) condition:

- When the chilled water supply temperature on chiller 3 is 40°F, and the return temperature increases above 54°F, add chiller 5, to maintain the load.

- Chillers 3 and 5, their associated chilled water pumps, condenser pumps, and cooling towers should be operated to maintain:

  - Minimum chilled water supply setpoint, 40°F.
  - Chilled water return temperature, 54°F.

- The chilled water setpoint should be adjusted to maintain the chilled water return temperature at 54°F.

High load (800 tons to 2,050 tons) condition:

- Chillers should be added on line in the following order, using the operational procedure of adding a chiller and adjusting the chilled water setpoint, to maintain a constant return water temperature of 54°F:

  - Chiller 4
  - Chiller 2
  - Chiller 1

Additional operational action items:

- No extra chilled water pumps should be run without an associated chiller.

- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as the chiller will tolerate, without surging or going off on safety controls, such as low refrigerant suction pressure, or as low as can be provided under the outdoor air conditions.

- The differential pressure controller and control valves on the discharge of the plant should be checked to determine the current operating condition of each.

Boilers:

The six HTHW boilers in Central Plant 5900 operate during the winter to meet the heating and DHW loads. No master boiler control is present to control staging of the boilers. When the last boiler was added to the central plant, the main HTHW flow meter in the central plant was not changed to measure the new maximum flow capacity from the central plant. As a result, operators cannot determine the heating capacity of the central plant. The main flow meter should be replaced and calibrated to match the maximum load flow condition from the central plant; the chart recorders should be adjusted to register the flows. With knowledge of the heating loads on the central plant, the boilers can be run more efficiently to meet the loads, thus minimizing standby losses and saving energy.

Various operating conditions of hot water temperatures and hot water pumping from Central Plant 5900 should be tested. To reduce distribution losses, hot water supply temperatures should be maintained at a minimum. To lower pumping energy requirements, the minimum number of hot water pumps should be run to meet the heating load.

6.2.9 Central Plant 6003

Chillers:

Central Plant 6003 has two 450 ton chillers which are operational and one 400 ton chiller which is not operational. The chillers in Central Plant 6003 will be run more efficiently if additional attention is directed at operating the chillers and pumps most suited to fit the estimated load. Although a sequence panel exists to operate the two chillers in a lead-lag manner based on current limits, the sequence panel was not used. Chiller 2 is experiencing mechanical problems. Cleaning the tubes and diagnosing and solving the mechanical problems will assure adequate capacity for the cooling load and will save energy by increasing efficiency.

Recommended operation of the chiller plant is as follows:

- The 400 ton chiller should be repaired and tested for its operating efficiency. If the efficiency of the 400 ton chiller is acceptable, the 400 ton chiller should be brought on line for the low load condition instead of the 450 ton chiller. The second 450 chiller would only be used as a standby. The chiller plant operation is described in the following page.

Low load (0 tons to 400 tons) condition:

- One 450 ton chiller, one main chilled water pump, one condenser water pump, and the north cooling tower should be operated to maintain:

  - Minimum chilled water supply setpoint, 42°F.
  - Chilled water return temperature, 58°F.

- The chilled water setpoint should be adjusted manually to maintain the chilled water return temperature at 58°F.

High load (400 tons to 850 tons) condition:

- When the chilled water supply temperature is set at 42°F, and the return temperature increases above 58°F, the second 450 ton chiller should be brought on line in addition to the first 450 ton chiller.

- The two 450 ton chillers, two chilled water pumps, two condenser water pumps, and both sets of cooling towers should be operated to maintain:

  - Minimum chilled water supply setpoint, 42°F.
  - Chilled water return temperature, 58°F.

- The chilled water setpoint should be adjusted manually to maintain the chilled water return temperature at 58°F.

Additional operational action items:

- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as the chiller will tolerate, without surging or going off on safety controls, such as low refrigerant suction pressure, or as low as can be provided under the outdoor air conditions.

<u>Boilers:</u>

Central Plant 6003 has three boilers, two of which operate during the winter to meet the heating and DHW needs. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

To maintain the longer boiler life associated with lower boiler temperatures and pressures, operators should also try lowering the boiler steam pressure from 10 psig to less (2 to 5 psig).

SECTION 7.0

INTERIM SUBMITTAL ENERGY CONSERVATION OPPORTUNITY SUMMARY

7.1 GENERAL

Using the evaluations of ECOs in Section 4.0, a summary of projects which meet technical and economic criteria was prepared. This summary is presented in the tables found in this section.

7.2 ECO SUMMARY

Table 7-1, on page 7-2, lists each ECO evaluated in the Interim Submittal, along with the ECO number designation. Table 7-2, beginning on page 7-3, lists all the ECOs evaluated by central plants. The table provides the predicted annual energy savings (type and amount), annual dollar savings, construction costs, and life cycle economics, including SIR and simple payback.

Table 7-3, beginning on page 7-8, provides the same list of ECO results, listed in order of descending SIR.

To qualify as an ECIP project, an ECO, or several ECOs which have been combined, must have a construction cost estimate greater than $200,000, a SIR greater than 1.0, and a simple payback less than eight years. Projects which normally do not meet ECIP criteria, but have an overall SIR greater than 1.0, are referenced as non-ECIP projects.

In summary, there are 26 projects evaluated in the Interim Submittal with an SIR greater than 1.0. The total savings and costs associated with these 26 projects are:

• Annual Electrical Savings (kWh):	2,117,581
• Annual Electrical Demand Savings (kW):	1,362
• Annual Natural Gas Savings (MMBtu):	55,273
• Total Energy Savings (MMBtu):	62,500
• Total First Year Annual Utility Cost Avoidance ($):	219,615
• Total Construction Cost ($):	1,127,328

TABLE 7-1
ECO LIST

ECO NUMBER	ECO DESCRIPTION	SPECIAL PROJECT - CENTRAL PLANT NUMBER
1.	Install instrumentation to establish chiller plant load to improve plant operations, thereby saving energy.	
2.	Control systems to match chiller capacity and characteristics with the load, thereby saving energy.	
3.	Renovate or replace chillers to improve efficiency, thereby saving energy.	
4.	Install ice storage cooling system to reduce peak air conditioning electrical demand.	
5.	5(A) - Install two-speed cooling tower fans to reduce cooling tower electrical energy. 5(B) - Install variable-speed cooling tower fans to reduce cooling tower electrical energy.	
6.	Install high efficiency motors to save electrical energy.	
7.	Install instrumentation establish boiler plant load to improve the plant operations, thereby saving energy.	
8.	Control systems to match boiler capacity and characteristics with the load, thereby saving energy.	
9.	Renovate or replace boilers to improve efficiency, thereby saving energy.	
10.	Install combustion controls to assure proper fuel-to-air ratio; increase combustion efficiency and save energy.	
11.	Install new high efficiency burners on boilers to increase combustion efficiency, thereby saving energy.	
12.	Installation stack economizer or air preheater to recover heat from the boiler stack, thereby saving energy.	
13.	Install chilled water variable speed pumping to improve flow and pressure drop in the distribution system, saving electrical energy.	5900
14.	Install a smaller pumps to match flow requirements, saving electrical energy.	730 & 4701
15.	Install a cogeneration, natural gas turbine engine, to generate electricity on-site, saving electrical demand and energy.	6003
16.	Install natural gas driven chillers to save electrical demand and energy.	2812
17.	Install electric boilers in building for summer DHW to shut down central plant in the summer, saving distribution loss and pumping energy.	730 & 2812

TABLE 7-2
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
730	1	129	243,000	0	829	$3,329	$2,766	$320	$5,620	9.6	0.9
	2	163	338,000	0	1,154	$4,631	$3,495	$1,077	$18,939	3.5	2.6
	3	22	2,000	0	7	$27	$472	$3,000	$6,330	-3.8	N/A
	4	712	0	0	0	$0	$15,268	$0	$192,000	0.9	12.6
	5(A)	0	17,441	0	60	$239	$0	$0	$14,890	0.2	59.3
	5(B)	0	18,709	0	64	$256	$0	$579	$10,180	-0.4	N/A
	6	41	85,430	0	292	$1,170	$879	$0	$50,297	0.5	23.3
	7	0	0	89	89	$260	$0	$255	$4,482	0.2	966.1
	10	0	0	108	108	$315	$0	$2,411	$29,654	-0.6	N/A
	14	0	144,560	0	493	$1,980	$0	$0	$12,809	1.9	6.2
	17	(121)	(48,800)	1,582	1,415	$3,951	($2,595)	$0	$38,431	1.2	27.0
914	3	93	130,000	0	444	$1,781	$1,994	$3,000	$3,165	2.2	3.9
	4	428	0	0	0	$0	$9,178	$0	$96,000	1.1	10.5
	5(B)	0	2,697	0	9	$37	$0	$361	$6,352	-0.6	N/A
	6	5	8,932	0	30	$122	$107	$0	$9,429	0.3	39.1
	7	0	0	11	11	$32	$0	$320	$5,620	-0.5	N/A

TABLE 7-2
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
914	8	0	0	44	44	$128	$0	$2,031	$33,847	-0.5	N/A
(Continued)	9	0	0	500	500	$1,460	$0	$3,000	$18,035	-0.5	N/A
2812	3	42	72,000	0	246	$986	$901	$3,000	$94,894	-0.2	N/A
	4	301	0	0	0	$0	$6,455	$0	$89,280	0.8	13.8
	5(A)	0	8,560	0	29	$117	$0	$0	$7,077	0.2	57.4
	5(B)	0	11,167	0	38	$153	$0	$298	$5,236	-0.4	N/A
	6	4	18,353	0	63	$251	$86	$0	$8,368	0.5	23.6
	7	0	0	21	21	$61	$0	$320	$5,620	-0.4	N/A
	8	0	0	307	307	$896	$0	$1,543	$27,128	-0.1	N/A
	9	0	0	621	621	$1813	$0	$1,056	$6,012	2.2	8.0
	16	144	278,000	(1,498)	(549)	($566)	$3,088	$384	$444,584	0.0	185.0
	17	(176)	(726,000)	7,346	4,868	$11,504	($3,774)	$0	$181,078	1.3	22.3
3442	1	0	209,000	0	713	$2,863	$0	$228	$4,012	6.0	1.5
	2	0	281,000	0	959	$3,850	$0	$936	$16,449	1.6	5.4
	4	780	0	0	0	$0	$16,726	$0	$288,000	0.7	17.2
	5(B)	0	35,884	0	122	$492	$0	$597	$10,499	-0.1	N/A
	6	4	12,880	0	44	$176	$86	$0	$25,318	0.1	92.1

TABLE 7-2
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
4701	1	0	71,000	0	242	$973	$0	$320	$5,620	3.1	2.9
	2	0	178,000	0	608	$2,439	$0	$234	$16,929	1.2	7.3
	3	113	126,000	0	430	$1,726	$2,423	$3,000	$218,314	0.1	180.7
	4	583	0	0	0	$0	$12,502	$0	$132,000	1.1	10.6
	5(B)	0	17,453	0	60	$239	$0	$1,013	$17,808	-0.5	N/A
	6	3	4,605	0	16	$63	$64	$0	$18,176	0.1	136.1
	7	0	0	61	61	$178	$0	$463	$8,145	-0.3	N/A
	10	0	0	160	160	$467	$0	$1,799	$24,869	-0.5	N/A
	12	0	0	89	89	$260	$0	$0	$46,799	0.1	198.0
	14	0	50,401	0	172	$690	$0	$0	$21,168	0.4	29.2
5676	3	96	137,000	0	468	$1,877	$2,059	$3,000	$94,320	0.1	95.9
	4	250	0	0	0	$0	$5,361	$0	$40,800	1.5	7.6
	5(A)	0	4,100	0	14	$56	$0	$0	$4,296	0.2	72.8
	5(B)	0	4,970	0	17	$68	$0	$289	$5,076	-0.5	N/A
	6	4	24,287	0	83	$333	$86	$0	$4,797	1.1	10.9
	7	0	0	13	13	$38	$0	$0	$5,620	-0.5	N/A
	9	0	0	5,520	5,520	$16,118	$0	$0	$105,344	1.6	11.8

TABLE 7-2
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
5676	10	0	0	238	238	$695	$0	$1,799	$24,869	0.3	21.4
(continued)	12	0	0	718	718	$2,097	$0	$0	$31,635	1.3	14.0
5678	4	142	0	0	0	$0	$3,045	$0	$48,000	0.7	15.8
	5(A)	0	3,873	0	13	$53	$0	$0	$4,296	0.2	77.0
	5(B)	0	4,721	0	16	$65	$0	$289	$5,076	-0.6	N/A
	6	3	14,412	0	49	$197	$64	$0	$4,821	0.7	17.5
	7	0	0	11	11	$32	$0	$320	$5,620	-0.5	N/A
	8	0	0	272	272	$794	$0	$1,632	$28,699	-0.2	N/A
	9	0	0	14,980	14,980	$43,742	$0	$3,000	$105,344	2.4	7.6
	10	0	0	1,537	1,537	$4,488	$0	$1,799	$24,869	1.7	8.9
	12	0	0	196	196	$572	$0	$0	$31,635	0.3	52.6
5900	1	0	519,104	0	1,772	$7,112	$0	$319	$5,620	11.1	0.8
	2	9	539,430	0	1,841	$7,390	$193	$1,188	$20,887	2.8	3.1
	3	154	718,000	0	2,451	$9,837	$3,302	$3,000	$49,465	0.6	14.8
	4	1,890	0	0	0	$0	$40,529	$0	$504,000	0.9	12.4
	5(A)	0	15,915	0	54	$218	$0	$0	$8,154	0.3	35.6
	5(B)	0	21,175	0	72	$290	$0	$425	$7,469	-0.2	N/A

TABLE 7-2
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
5900	6	28	42,400	0	145	$581	$600	$0	$58,343	0.2	47.0
(Continued)	7	0	0	161	161	$470	$0	$306	$5,377	0.6	31.2
	8	0	0	6,157	6,157	$17,978	$0	$2,745	$48,257	4.3	3.0
	9	0	0	7,241	7,241	$21,144	$0	$1,792	$12,685	20.5	0.6
	10	0	0	3,182	3,182	$9,291	$0	$4,247	$44,010	1.9	8.3
	12	0	0	6,389	6,389	$18,656	$0	$0	$140,396	2.5	7.2
	13	0	203,000	0	693	$2,781	$0	$2,507	$157,969	0.0	547.0
6003	1	0	215,000	0	734	$2,946	$0	$320	$5,620	5.3	1.7
	4	544	0	0	0	$0	$11,666	$0	$204,000	0.7	17.5
	5(A)	0	25,818	0	88	$354	$0	$0	$11,002	0.4	29.6
	5(B)	0	31,025	0	106	$425	$0	$570	$10,021	-0.2	N/A
	6	12	25,861	0	88	$354	$257	$0	$23,185	0.3	36.1
	7	0	0	67	67	$196	$0	$255	$4,482	0.0	N/A
	10	0	0	450	450	$1,314	$0	$1,187	$20,083	0.3	150.4
	15	417	977,000	(49,603)	(46,268)	($131,456)	$8,942	$3,000	NA		

TABLE 7-3
ECONOMIC SUMMARY OF ECOs LISTED BY SIR

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC.ENERGY SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
5900	9	0	0	7,241	7,241	$21,144	$0	$1,792	$12,685	20.5	0.6
5900	1	0	519,104	0	1,772	$7,112	$0	$319	$5,620	11.1	0.8
730	1	129	243,000	0	829	$3,329	$2,766	$320	$5,620	9.6	0.9
3442	1	0	209,000	0	713	$2,863	$0	$228	$4,012	6.0	1.5
6003	1	0	215,000	0	734	$2,946	$0	$320	$5,620	5.3	1.7
5900	8	0	0	6,157	6,157	$17,978	$0	$2,745	$48,257	4.3	3.0
730	2	163	338,000	0	1,154	$4,631	$3,495	$1,077	$18,939	3.5	2.6
4701	1	0	71,000	0	242	$973	$0	$320	$5,620	3.1	2.9
5900	2	9	539,430	0	1,841	$7,390	$193	$1,188	$20,887	2.8	3.1
5900	12	0	0	6,389	6,389	$18,656	$0	$0	$140,396	2.5	7.2
5678	9	0	0	14,980	14,980	$43,742	$0	$3,000	$105,344	2.4	7.6
2812	9	0	0	621	621	$1,813	$0	$1,056	$6,012	2.2	8.0
914	3	93	130,000	0	444	$1,781	$1,994	$3,000	$3,165	2.2	3.9
730	14	0	144,560	0	493	$1,980	$0	$0	$12,809	1.9	6.2
5900	10	0	0	3,182	3,182	$9,291	$0	$4,247	$44,010	1.9	8.3
5678	10	0	0	1,537	1,537	$4,488	$0	$1,799	$24,869	1.7	8.9
3442	2	0	281,000	0	959	$3,850	$0	$936	$16,449	1.6	5.4
5676	9	0	0	5,520	5,520	$16,118	$0	$0	$105,344	1.6	11.8

TABLE 7-3
ECONOMIC SUMMARY OF ECOs LISTED BY SIR

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC.ENERGY SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
5676	4	250	0	0	0	$0	$5,361	$0	$40,800	1.5	7.6
2812	17	(176)	(726,000)	7,346	4,868	$11,504	($3,774)	$0	$181,078	1.3	22.3
5676	12	0	0	718	718	$2,097	$0	$0	$31,635	1.3	14.0
4701	2	0	178,000	0	608	$2,439	$0	$234	$16,929	1.2	7.3
730	17	(121)	(48,800)	1,582	1,415	$3,951	($2,595)	$0	$38,431	1.2	27.0
914	4	428	0	0	0	$0	$9,178	$0	$96,000	1.1	10.5
4701	4	583	0	0	0	$0	$12,502	$0	$132,000	1.1	10.6
5676	6	4	24,287	0	83	$333	$86	$0	$4,797	1.1	10.9
5900	4	1,890	0	0	0	$0	$40,529	$0	$504,000	0.9	12.4
730	4	712	0	0	0	$0	$15,268	$0	$192,000	0.9	12.6
2812	4	301	0	0	0	$0	$6,455	$0	$89,280	0.8	13.8
5678	4	142	0	0	0	$0	$3,045	$0	$48,000	0.7	15.8
3442	4	780	0	0	0	$0	$16,726	$0	$288,000	0.7	17.2
6003	4	544	0	0	0	$0	$11,666	$0	$204,000	0.7	17.5
5678	6	3	14,412	0	49	$197	$64	$0	$4,821	0.7	17.5
5900	7	0	0	161	161	$470	$0	$306	$5,377	0.6	31.2
5900	3	154	718,000	0	2,451	$9,837	$3,302	$3,000	$49,465	0.6	14.8
730	6	41	85,430	0	292	$1,170	$879	$0	$50,297	0.5	23.3

TABLE 7-3
ECONOMIC SUMMARY OF ECOs LISTED BY SIR

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC.ENERGY SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
2812	6	4	18,353	0	63	$251	$86	$0	$8,368	0.5	23.6
4701	14	0	50,401	0	172	$690	$0	$0	$21,168	0.4	29.2
6003	5(A)	0	25,818	0	88	$354	$0	$0	$11,002	0.4	29.6
5676	10	0	0	238	238	$695	$0	$1,799	$24,869	0.3	21.4
5678	12	0	0	196	196	$572	$0	$0	$31,635	0.3	52.6
5900	5(A)	0	15,915	0	54	$218	$0	$0	$8,154	0.3	35.6
6003	6	12	25,861	0	88	$354	$257	$0	$23,185	0.3	36.1
914	6	5	8,932	0	30	$122	$107	$0	$9,429	0.3	39.1
6003	10	0	0	450	450	$1,314	$0	$1,187	$20,083	0.3	150.4
5900	6	28	42,400	0	145	$581	$600	$0	$58,343	0.2	47.0
730	7	0	0	89	89	$260	$0	$255	$4,482	0.2	966.1
2812	5(A)	0	8,560	0	29	$117	$0	$0	$7,077	0.2	57.4
730	5(A)	0	17,441	0	60	$239	$0	$0	$14,890	0.2	59.3
5676	5(A)	0	4,100	0	14	$56	$0	$0	$4,296	0.2	72.8
5678	5(A)	0	3,873	0	13	$53	$0	$0	$4,296	0.2	77.0
3442	6	4	12,880	0	44	$176	$86	$0	$25,318	0.1	92.1
5676	3	96	137,000	0	468	$1,877	$2,059	$3,000	$94,320	0.1	95.9
4701	12	0	0	89	89	$260	$0	$0	$46,799	0.1	198.0

TABLE 7-3
ECONOMIC SUMMARY OF ECOs LISTED BY SIR

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC.ENERGY SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
4701	6	3	4,605	0	16	$63	$64	$0	$18,176	0.1	136.1
4701	3	113	126,000	0	430	$1,726	$2,423	$3,000	$218,314	0.1	180.7
6003	7	0	0	67	67	$196	$0	$255	$4,482	0.0	N/A
5900	13	0	203,000	0	693	$2,781	$0	$2,507	$157,969	0.0	547.0
2812	16	144	278,000	(1,498)	(549)	($566)	$3,088	$384	$444,584	0.0	185.0
2812	8	0	0	307	307	$896	$0	$1,543	$27,128	-0.1	N/A
3442	5(B)	0	35,884	0	122	$492	$0	$597	$10,499	-0.1	N/A
2812	3	42	72,000	0	246	$986	$901	$3,000	$94,894	-0.2	N/A
5678	8	0	0	272	272	$794	$0	$1,632	$28,699	-0.2	N/A
6003	5(B)	0	31,025	0	106	$425	$0	$570	$10,021	-0.2	N/A
5900	5(B)	0	21,175	0	72	$290	$0	$425	$7,469	-0.2	N/A
4701	7	0	0	61	61	$178	$0	$463	$8,145	-0.3	N/A
2812	5(B)	0	11,167	0	38	$153	$0	$298	$5,236	-0.4	N/A
730	5(B)	0	18,709	0	64	$256	$0	$579	$10,180	-0.4	N/A
2812	7	0	0	21	21	$61	$0	$320	$5,620	-0.4	N/A
4701	10	0	0	160	160	$467	$0	$1,799	$24,869	-0.5	N/A
5676	7	0	0	13	13	$38	$0	$0	$5,620	-0.5	N/A
914	7	0	0	11	11	$32	$0	$320	$5,620	-0.5	N/A

TABLE 7-3
ECONOMIC SUMMARY OF ECOs LISTED BY SIR

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC.ENERGY SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
5678	7	0	0	11	11	$32	$0	$320	$5,620	-0.5	N/A
914	8	0	0	44	44	$128	$0	$2,031	$33,847	-0.5	N/A
914	9	0	0	500	500	$1,460	$0	$3,000	$18,035	-0.5	N/A
4701	5(B)	0	17,453	0	60	$239	$0	$1,013	$17,808	-0.5	N/A
5676	5(B)	0	4,970	0	17	$68	$0	$289	$5,076	-0.5	N/A
5678	5(B)	0	4,721	0	16	$65	$0	$289	$5,076	-0.6	N/A
914	5(B)	0	2,697	0	9	$37	$0	$361	$6,352	-0.6	N/A
730	10	0	0	108	108	$315	$0	$2,411	$29,654	-0.6	N/A
730	3	22	2,000	0	7	$27	$472	$3,000	$6,330	-3.8	N/A
6003	15	417	977,000	(49,603)	(46,268)	($131,456)	$8,942	$3,000	N/A	N/A	N/A

SECTION 8.0

ENERGY CONSERVATION PROJECTS

8.1 PROJECTS DEVELOPED

At the Interim Submittal review conference with Fort Sill DEH, the individual ECOs which were determined to be economically viable were reviewed. The individual ECOs were either grouped into projects or eliminated because of functional decision making. Five projects were developed from the individual ECOs. These projects were evaluated to determine if they were economically feasible for funding under the Energy Conservation Investment Program (ECIP). The five projects developed for further analysis included:

- Project 1 - Control project for Central Plants 730, 5900, and 6003: Install microprocessor-based instrumentation and controls to remotely monitor and control mechanical equipment in central plants. The control system monitors central plant loads and selects appropriate equipment to match the equipment capacity with the load, thereby saving energy.

- Project 2 - Central heating plant project and control project for Buildings 5676 and 5678: Expand existing Central Plant 5678 to provide heating. Boilers and pumps are replaced to improve efficiency, thereby saving energy.

- Project 3 - Replacement of boilers 1 and 2 in Central Plants 2812 and 5900: Replace Boilers 1 and 2 in Central Plants 2812 and 5900 to improve boiler efficiency, thereby saving energy.

- Project 4 - Replacement of chiller in Central Plant 2812 with a higher efficiency chiller: Replace chiller in Central Plant 2812 with a high efficiency chiller matched to the central plant loads, thereby saving energy.

- Project 5 - Comparison of local hot water boiler in each barracks versus central heating plant project, 3400 Area: Compare replacement of steam boilers with high efficiency modular hot water boilers in barracks versus constructing a central HTHW heating plant to provide hot water.

8.1.1 Project 1 - Control Project for Central Plants 730, 5900, and 6003

INSTALL AN AUTOMATED CONTROL SYSTEM

Premise:
This project proposes to install an automated control system on mechanical equipment in Central Plants 730, 5900, and 6003. The control and monitoring points for the central plants included the following:

Boiler
- Boiler stack temperature and O_2
- Boiler alarm
- Hot water pump start/stop and status
- Supply and return hot water temperatures
- Flow of the supply steam and hot water
- Supply pressure for steam and nitrogen in the expansion tank for high temperature hot water
- Natural gas line pressure before and after the regulator
- Natural gas metering
- Flow and accumulation of the make-up water
- Local displays

Chiller
- Chilled water supply and return temperatures
- Condenser water supply and return temperatures
- Flow of the chilled water
- Chiller start/stop and status
- Chiller temperature control
- Chiller alarm
- Chiller kW consumption
- Cooling towers start/stop and status
- Chilled water pump start/stop and status
- Condenser water pump start/stop and status
- Local displays

Figures 8-1 through 8-6, on pages 8-4 through 8-9, graphically depict control and monitoring points for Central Plants 730, 5900, and 6003. The Legend symbols are shown in Figure 8-7 on page 8-11.

This project is essentially a combination of ECOs 1, 2, 7, and 8, which were discussed in the Interim Submittal. This project proposes to install a new automated control system to determine central plant loads and optimize the operation of the mechanical equipment in the central plants. The new automated control system will be tied together and connected to an existing automated control system which has a central PC-based computer located in the RVAC shop, Building 1950. The new automated control system will utilize a fiber optic data transmission system between the central plants and Building 1950.
(Continued)

INSTALL AN AUTOMATED CONTROL SYSTEM (Concluded)

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this project. The chiller, boiler, and pump sequences of operation were changed from the sequences used in the baseline, to better match the required load. The Chiller and Boiler Identification Numbers were resequenced to simulate starting chillers and boiler in a different order.

The energy saved by this project is the difference between the baseline and the project computer simulations. See Appendix I for the project backup calculation and computer simulation output.

Results:

Annual Electricity Savings (kWh):	1,507,208
Peak Electrical Demand Savings (kW):	164
Annual Natural Gas Savings (MMBtu):	7,682
Total Annual Utility Cost Savings:	$43,080
Analysis Period:	15 Years
Estimated Construction Cost:	$608,539
Simple Payback:	32.8 Years
Savings-to-Investment Ratio (SIR):	0.5

Recommendation: Do not Implement

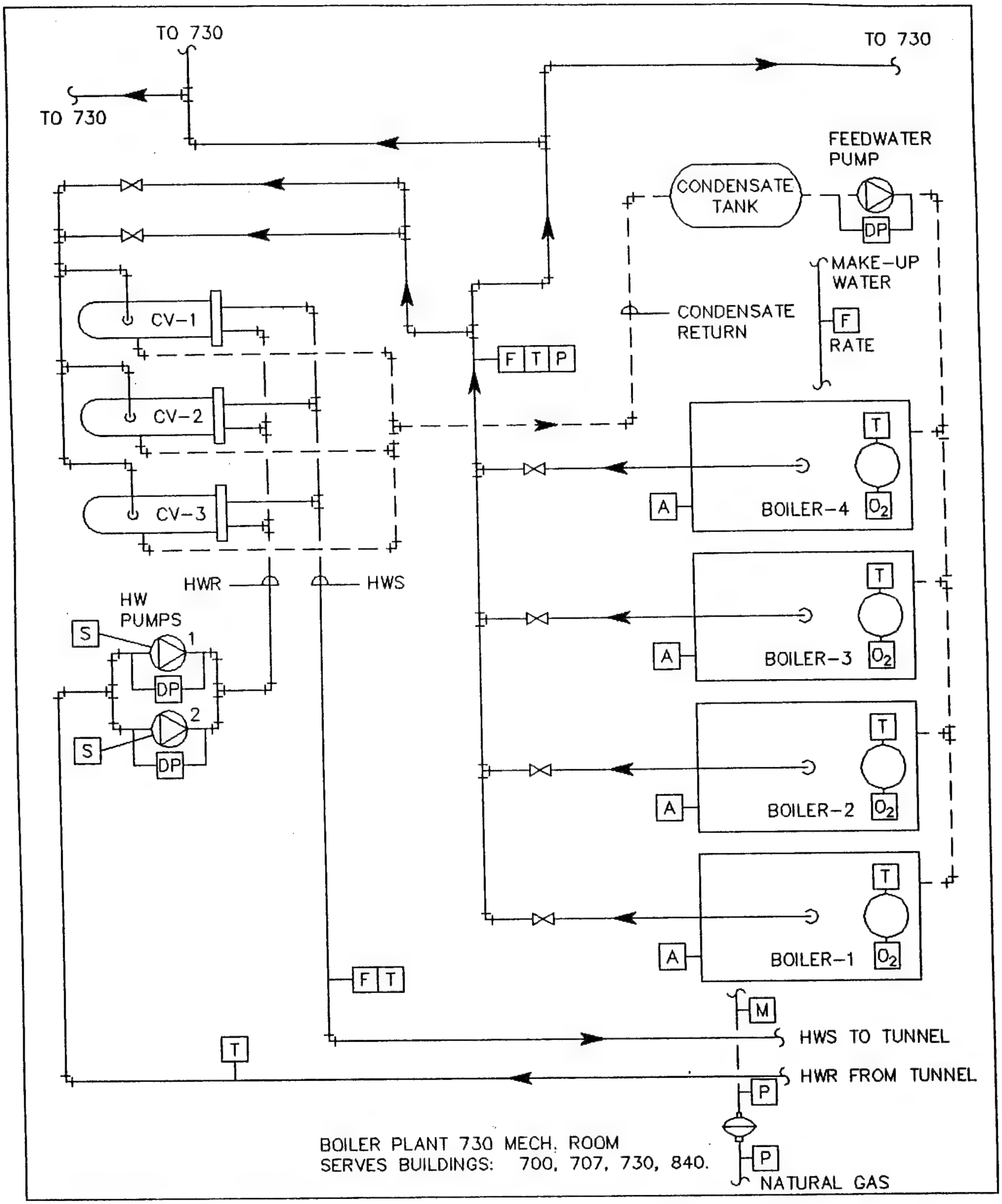


FIGURE 8-1. CONTROL SCHEMATIC OF BOILERS, CENTRAL PLANT 730

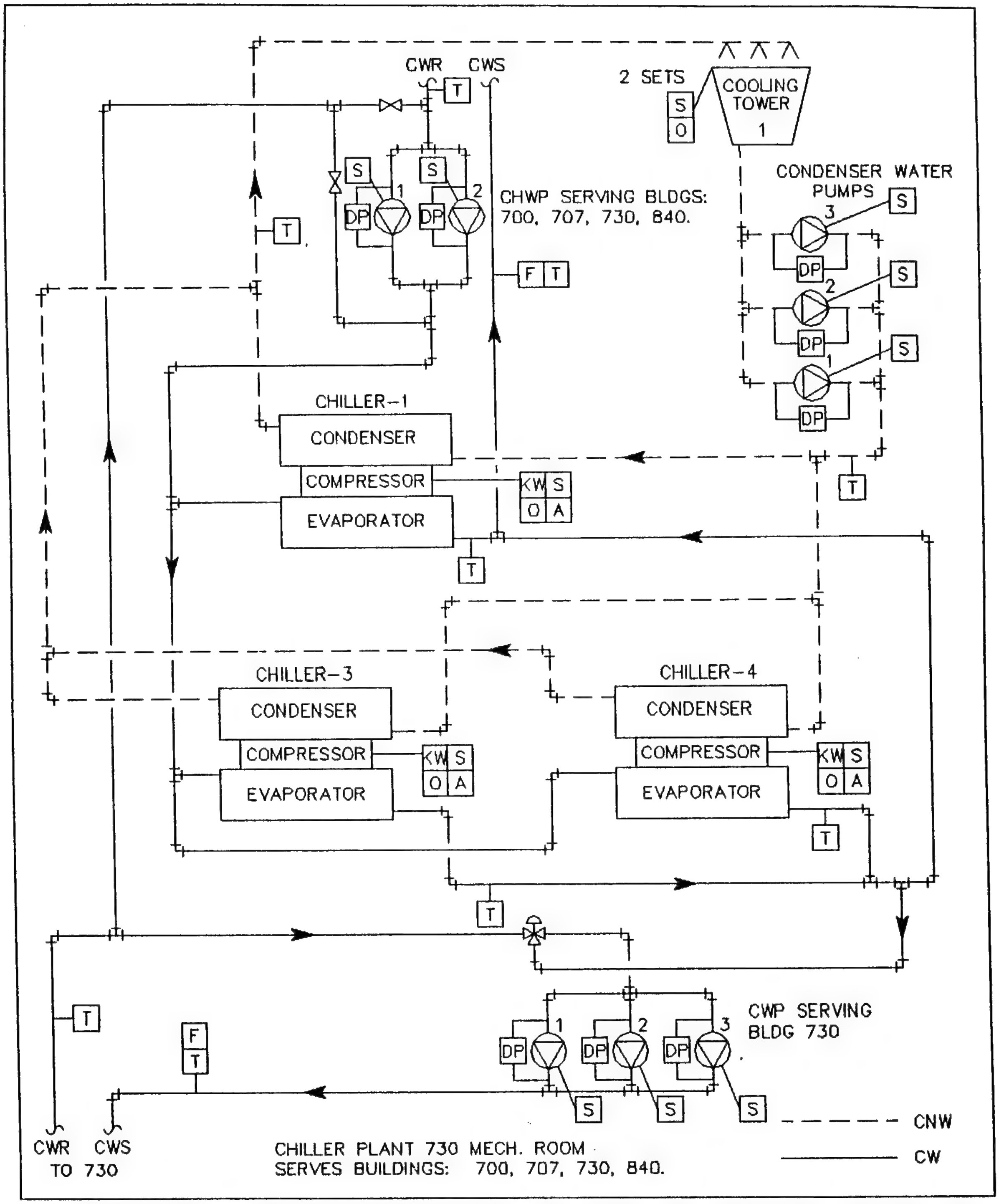


FIGURE 8-2. CONTROL SCHEMATIC OF CHILLERS, CENTRAL PLANT 730

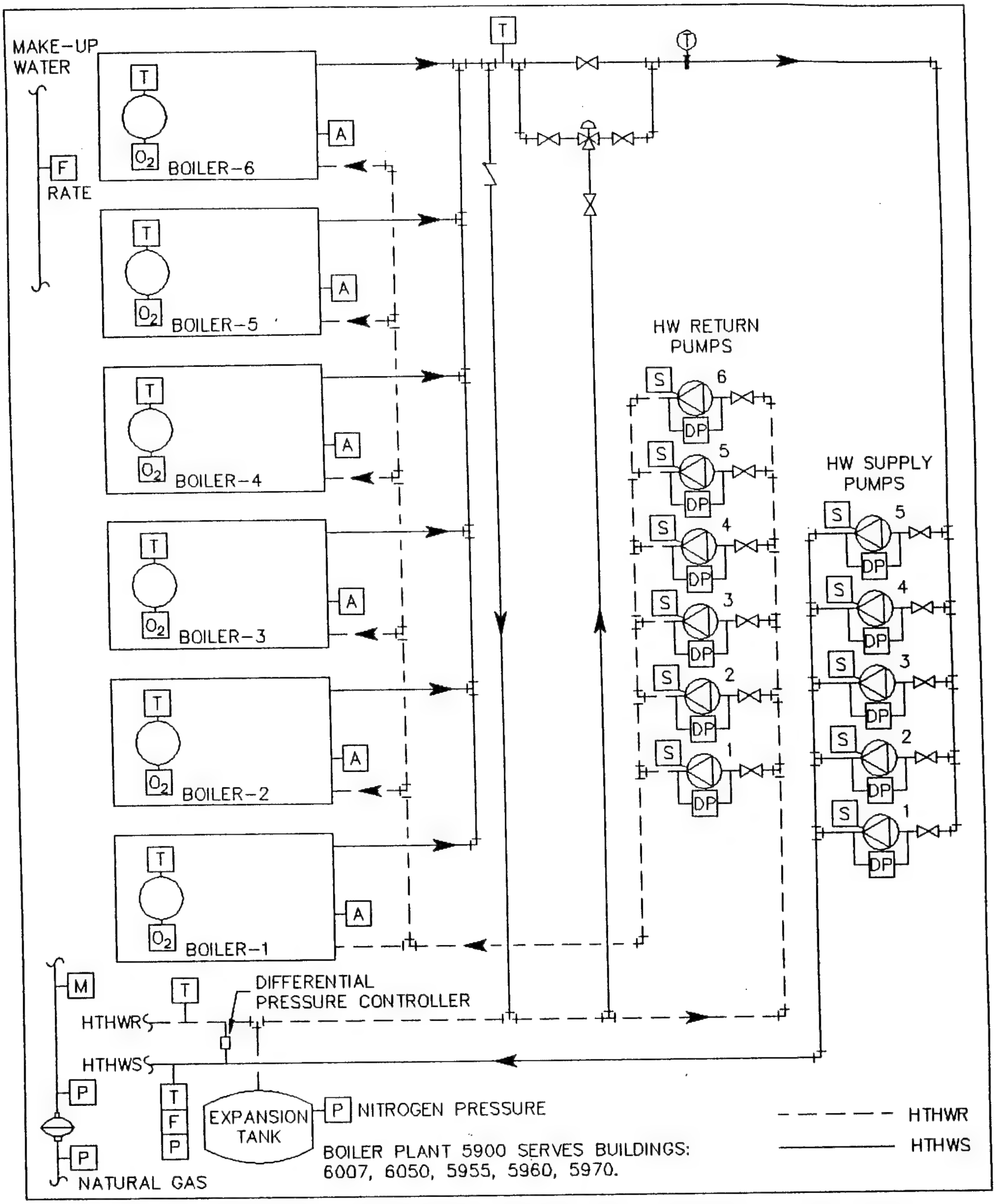


FIGURE 8-3. CONTROL SCHEMATIC OF BOILERS, CENTRAL PLANT 5900

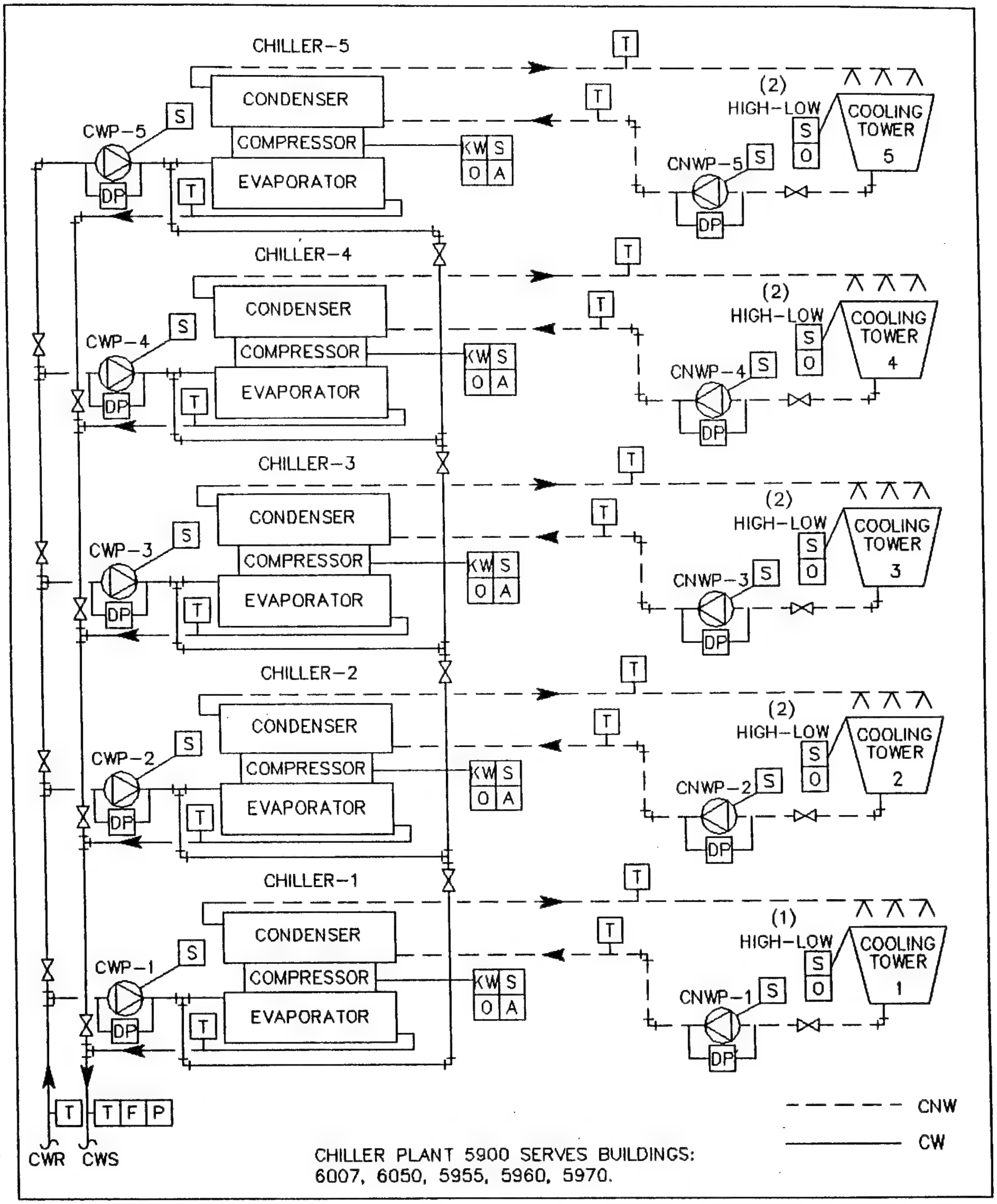


FIGURE 8-4. CONTROL SCHEMATIC OF CHILLERS, CENTRAL PLANT 5900

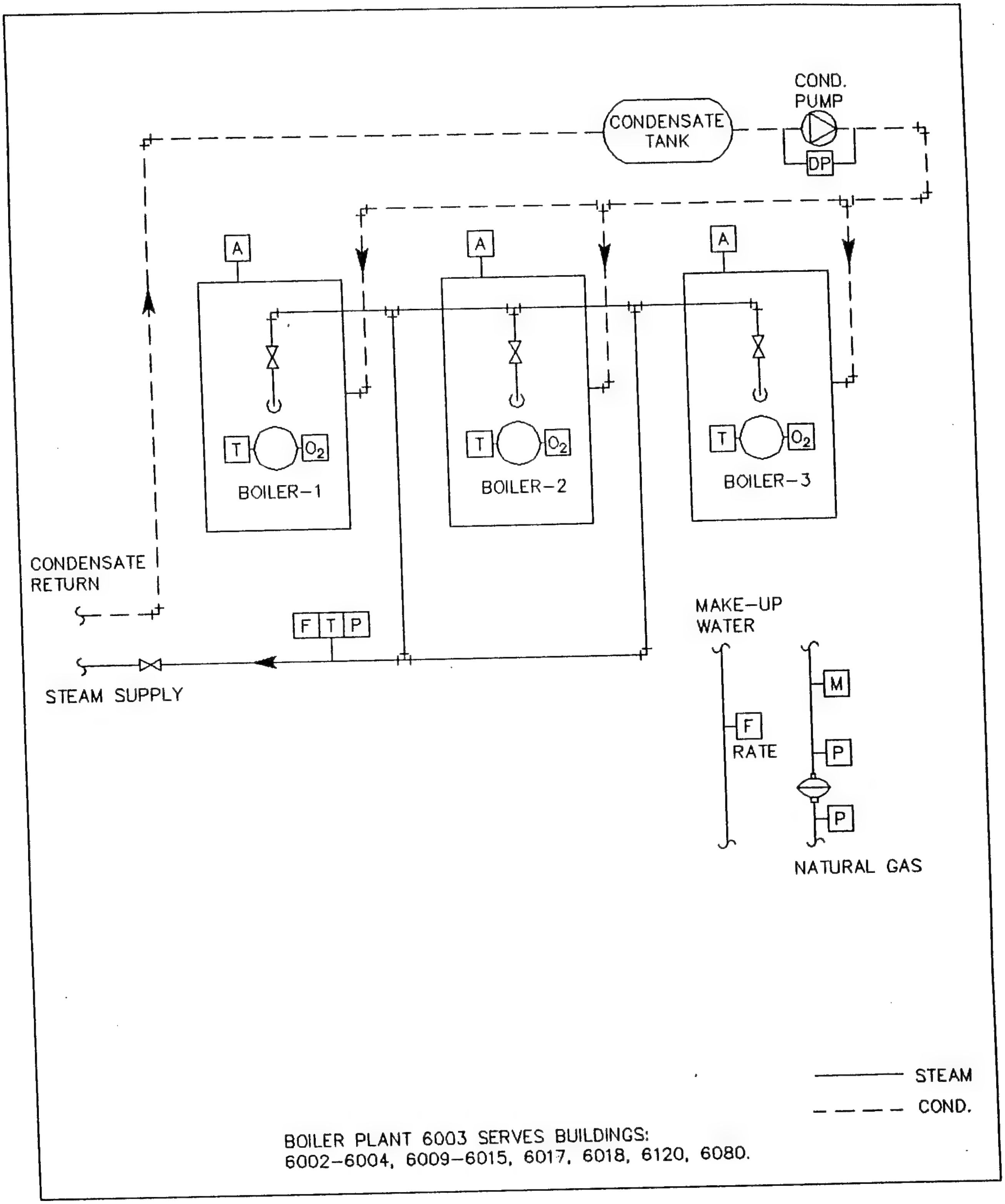


FIGURE 8-5. CONTROL SCHEMATIC OF BOILERS, CENTRAL PLANT 6003

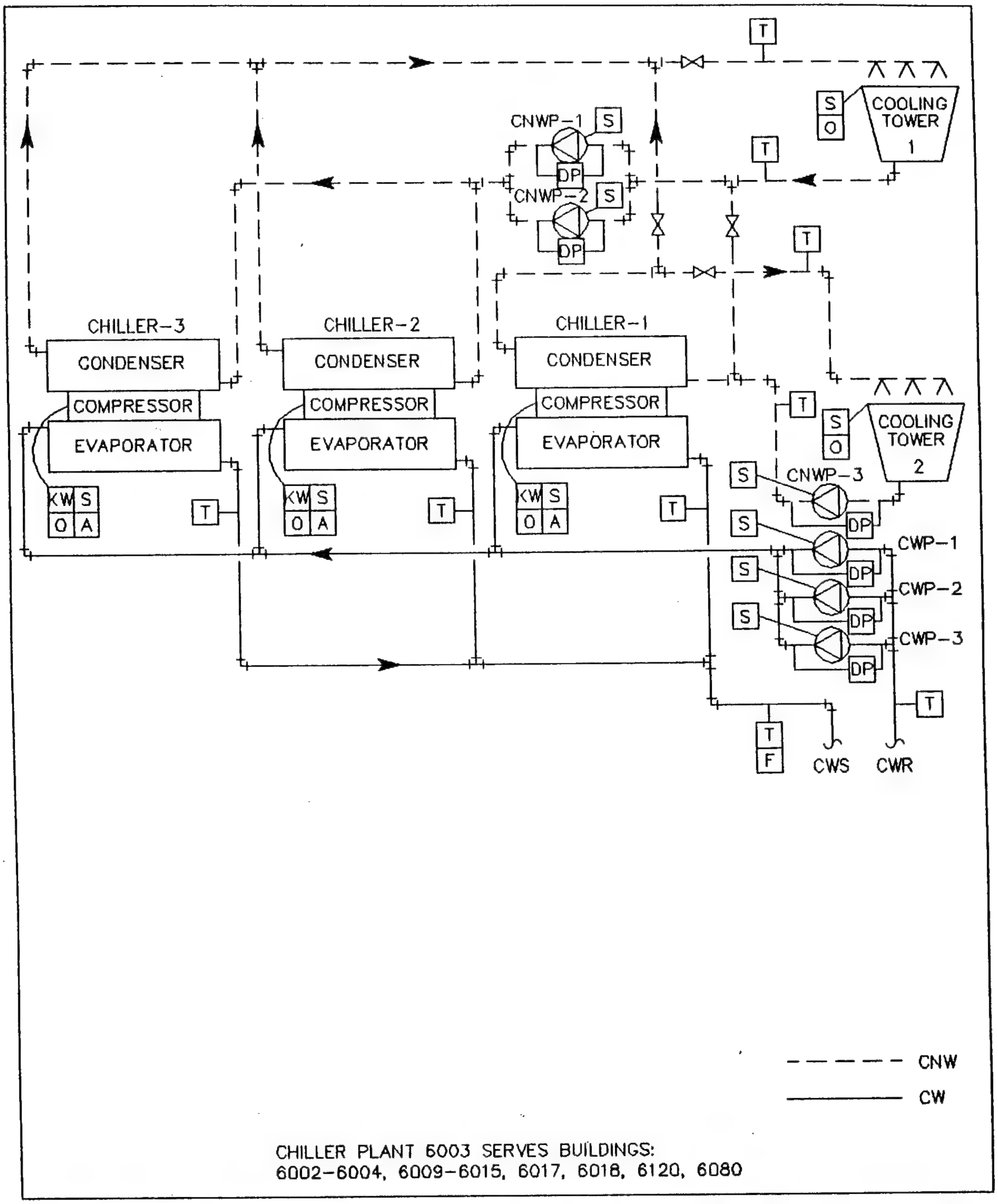


FIGURE 8-6. CONTROL SCHEMATIC OF CHILLERS, CENTRAL PLANT 6003

8.1.2 Project 2 - Central Heating Plant and Control Project for Buildings 5676 and 5678

CENTRAL HEATING PLANT IN BUILDING 5678 TO PROVIDE HEATING FOR BUILDINGS 5676 AND 5678

Premise:
This project proposes to replace boilers and HW pumps in the central plant in Building 5678 to provide heating for Buildings 5676 and 5678. Figure 8-8 on page 8-12 graphically depicts the new heating distribution plan. The central heating plant will have the following new equipment:

- 8 modular boilers
- 2 hot water pumps.

Figure 8-9 on page 8-13 graphically depicts the layout of the new central heating plant addition. In addition to new mechanical equipment, this project also proposes to install an automated control system on all mechanical equipment in Central Plant 5678. This project is essentially a combination of ECOs 6, 7, 8, and 9 (see Table 7-1, page 7-2). The control and monitoring points for the central plant will have similar control and monitoring points as Project 1, Section 8.2.1, to help increase system efficiencies and save energy.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this project. The boilers and pumps input data were changed to simulate new mechanical equipment. The boilers and pumps sequences of operation were configured to match the required load.

The energy saved by this project is the difference between the baseline and the project computer simulations. See Appendix J for the project backup calculation and computer simulation output.

Results:

Annual Electricity Savings (kWh):	0
Peak Electrical Demand Savings (kW):	0
Annual Natural Gas Savings (MMBtu):	2,956
Total Annual Utility Cost Savings:	$8,632
Analysis Period:	25 Years
Estimated Construction Cost:	$309,222
Simple Payback:	58 Years
Savings-to-Investment Ratio (SIR):	0.5

Recommendation: Do not implement

SYMBOLS LEGEND

A	ALARM CONTACT SIGNAL
F	FLOW INDICATION
P	PRESSURE INDICATION
M	METER
O	ON-OFF STATUS SIGNAL
DP	DIFFERENTIAL PRESSURE SWITCH
S	START-UP INTERFACE
T	TEMPERATURE INDICATION
O_2	FLUE GAS ANALYSIS, OXYGEN
KW	KILOWATT METER
	EXISTING-TO-NEW

FIGURE 8-7. LEGEND

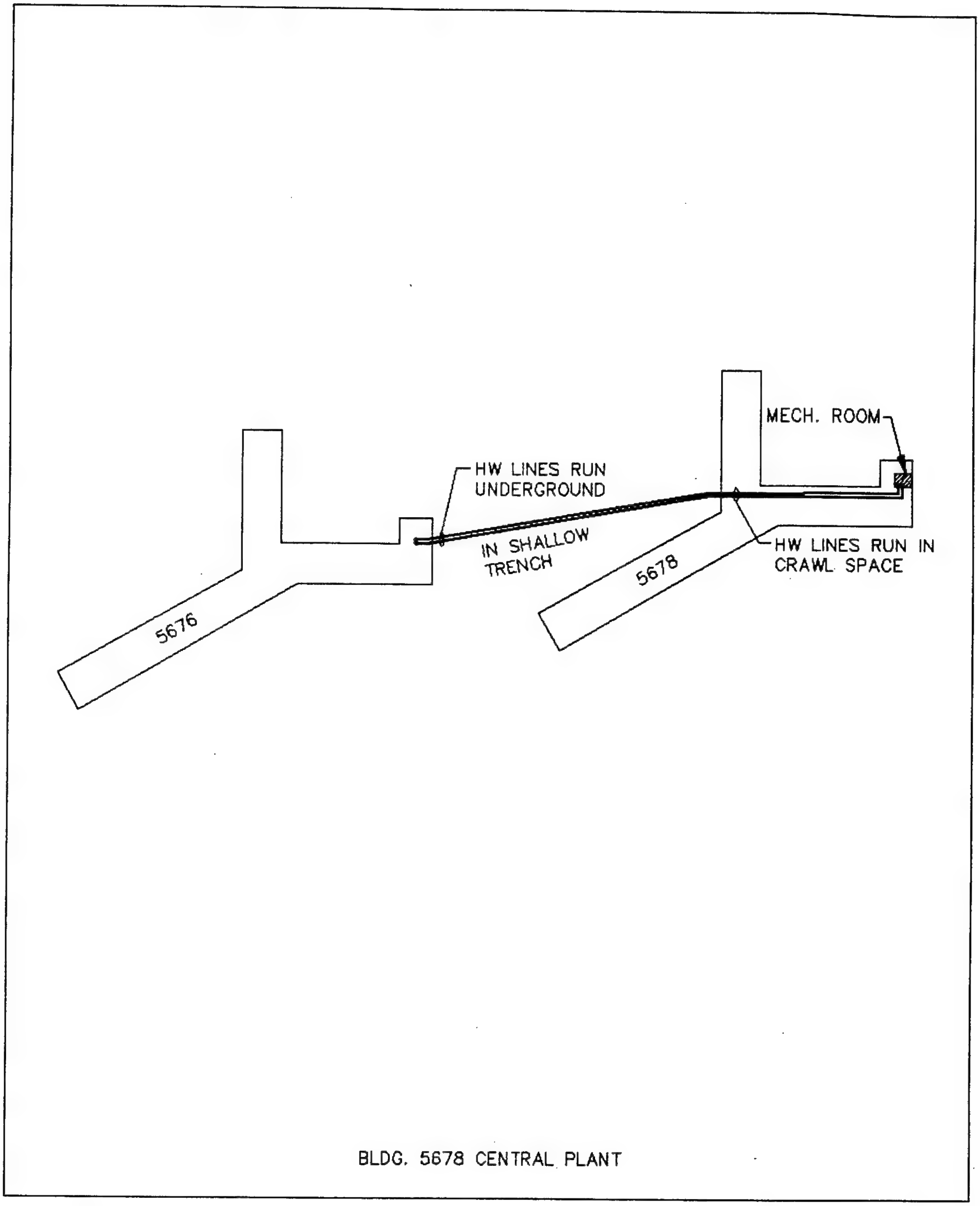


FIGURE 8-8. DISTRIBUTION PLAN, CENTRAL PLANT 5678

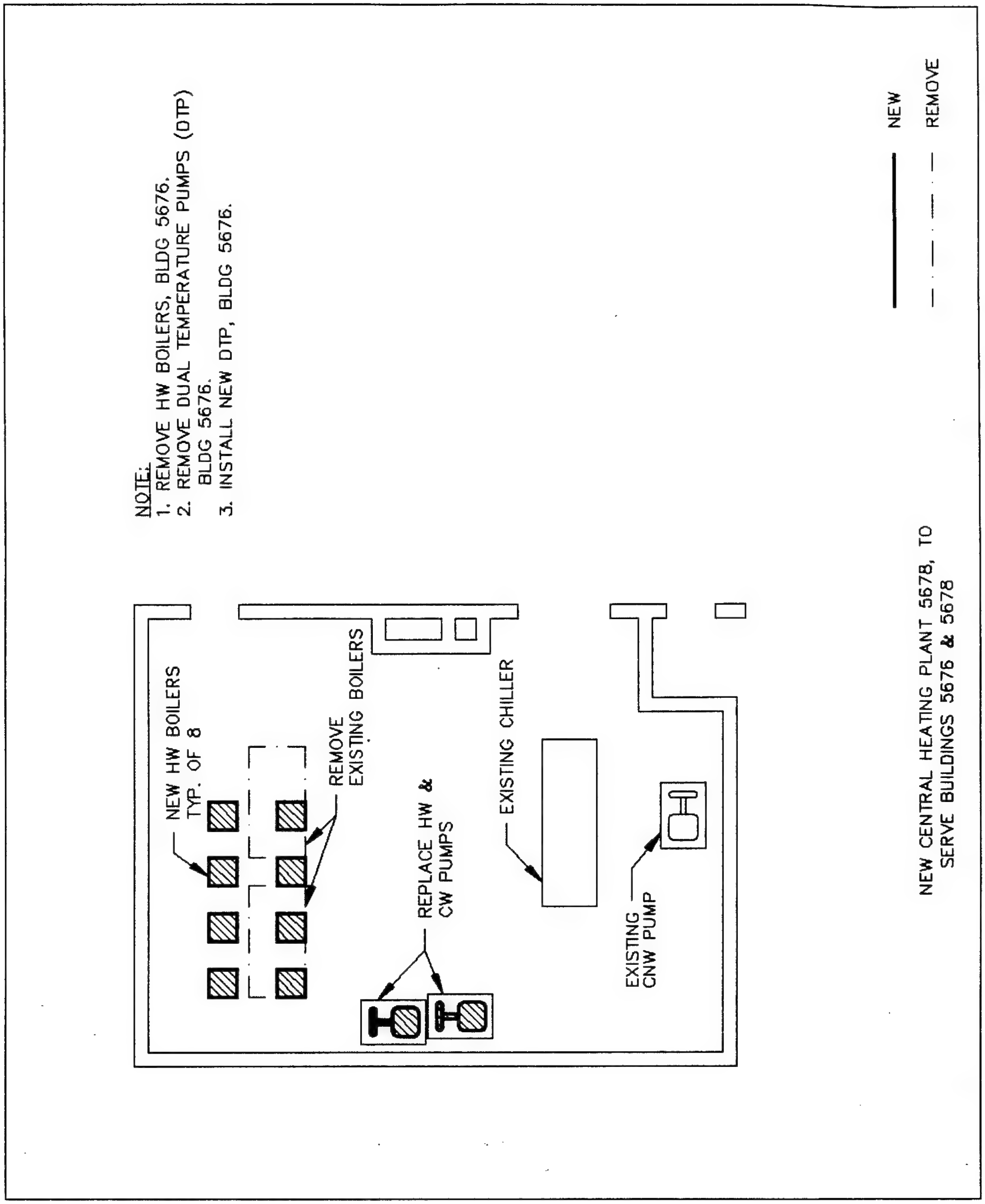


FIGURE 8-9. MECHANICAL ROOM LAYOUT, CENTRAL PLANT 5678

8.1.3 Project 3 - Replace Boilers 1 and 2 in Central Plants 2812 and 5900

REPLACE EXISTING BOILERS WITH HIGHER EFFICIENCY BOILERS

Premise:
This project proposes to replace boilers 1 and 2 in Central Plants 2812 and 5900. New high efficiency pumps will be installed in Central Plant 2812; no pumps will be replaced in Central Plant 5900. Figures 8-10 and 8-11, on pages 8-15 and 8-16, graphically depict the layout of new boilers in the mechanical rooms. This project is essentially a combination of ECOs 1, 2, 6, 7, 8, and 9 (see Table 1, page 7-2). Control and monitoring points for new boilers will be similar to those for the boilers in Project 1, Section 8.2.1; these controls will help increase system efficiencies and save energy.

Central Plant 2812 will have the following new equipment:

- 8 modular boilers
- 2 hot water pumps

Central Plant 5900 will have the following new equipment:

- 2 HTHW boilers

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this project. The input data was revised to increase boiler efficiency.

The energy saved by this project is the difference between the baseline and the project computer simulations. See Appendix L for the computer simulation output.

Results:

Annual Electricity Savings (kWh):	122,000
Peak Electrical Demand Savings (kW):	14
Annual Natural Gas Savings (MMBtu):	29,160
Total Annual Utility Cost Savings:	$86,819
Analysis Period:	25 Years
Estimated Construction Cost:	$493,543
Simple Payback:	6.23 Years
Savings-to-Investment Ratio (SIR):	3.84

Recommendations: Implement

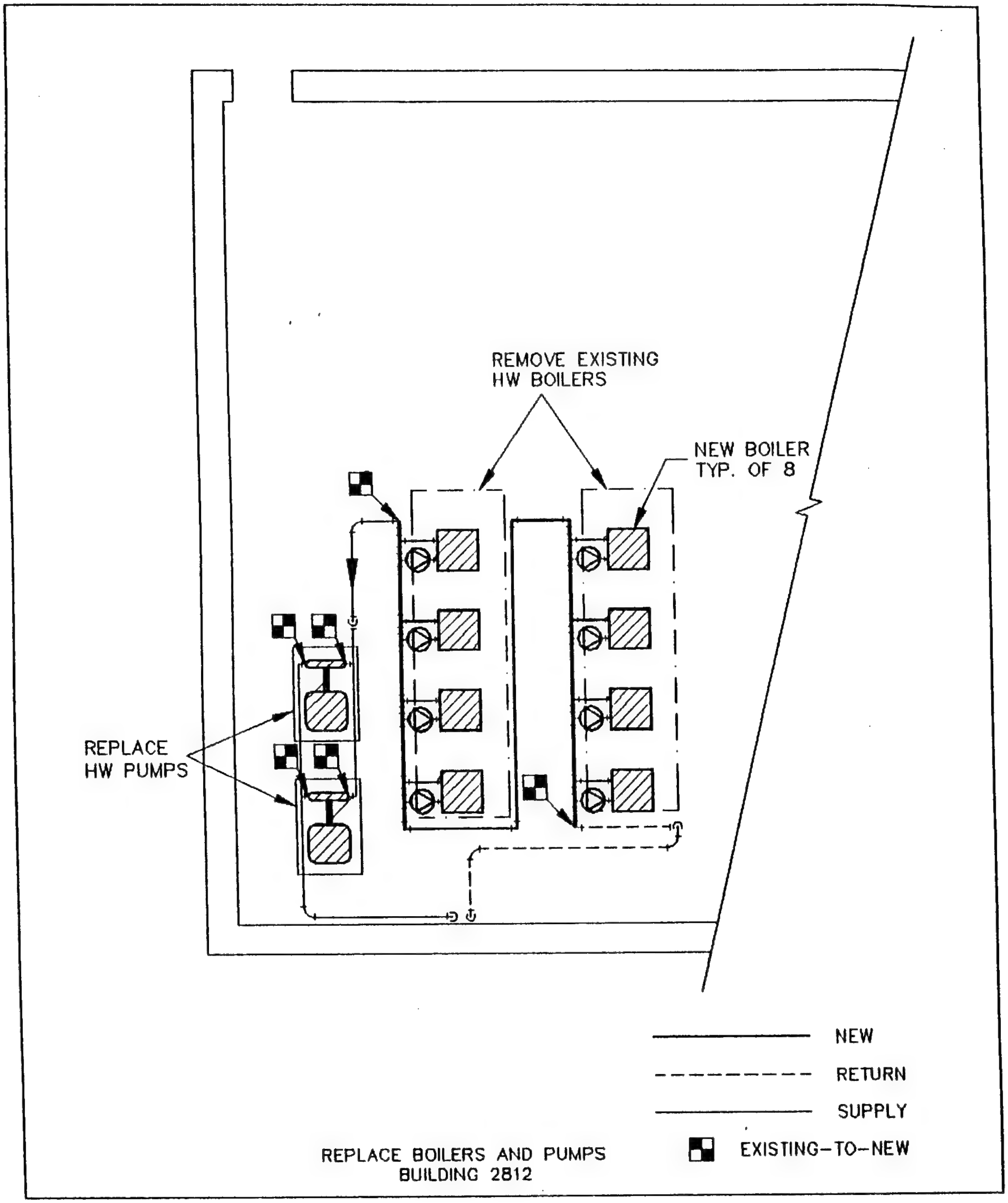


FIGURE 8-10. MECHANICAL ROOM LAYOUT, CENTRAL PLANT 2812

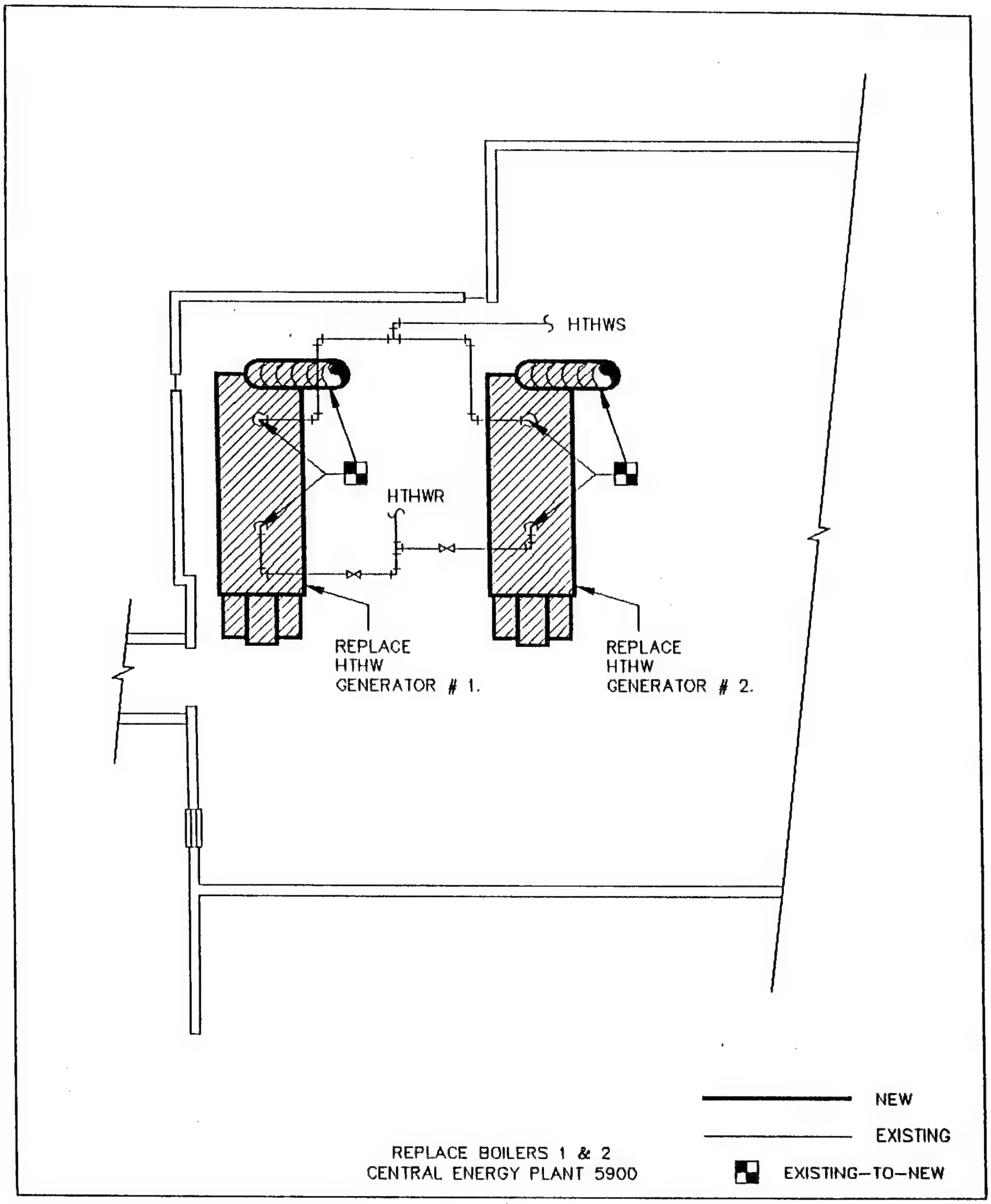


FIGURE 8-11. MECHANICAL ROOM LAYOUT, CENTRAL PLANT 5900

8.1.4 Project 4 - Replace Chiller in Central Plant 2812

REPLACE EXISTING CHILLER WITH HIGH EFFICIENCY CHILLER

Premise:
This project proposes to replace the chiller in Central Plant 2812 with a high efficiency chiller, matched to the existing cooling loads, to obtain a higher efficiency and better match of capacity to load. New high efficiency chilled water and condenser water pumps will also be installed in Central Plant 2812. Figure 8-12 on page 8-18 graphically depicts the layout of the new chiller and pumps in the mechanical room. The new chiller will have control and monitoring points similar to those for the chillers in Project 1, Section 8.2.1; these controls will help increase system efficiencies and save energy.

The central plant will have the following new equipment:

- 1 chiller (342 tons)
- 2 pumps (1 CWP and 1 CNWP)

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this project. The input data was revised to increase chiller efficiency.

The energy saved by this project is the difference between the baseline and the project computer simulations. See Appendix M for the backup calculation and computer simulation output.

Results:

Annual Electricity Savings (kWh):	78,000
Peak Electrical Demand Savings (kW):	23
Annual Natural Gas Savings (MMBtu):	0
Total Annual Utility Cost Savings:	$1,069
Analysis Period:	25 Years
Estimated Construction Cost:	$208,111
Simple Payback:	(Savings less than cost)
Savings-to-Investment Ratio (SIR):	NA

Recommendations: Do not implement

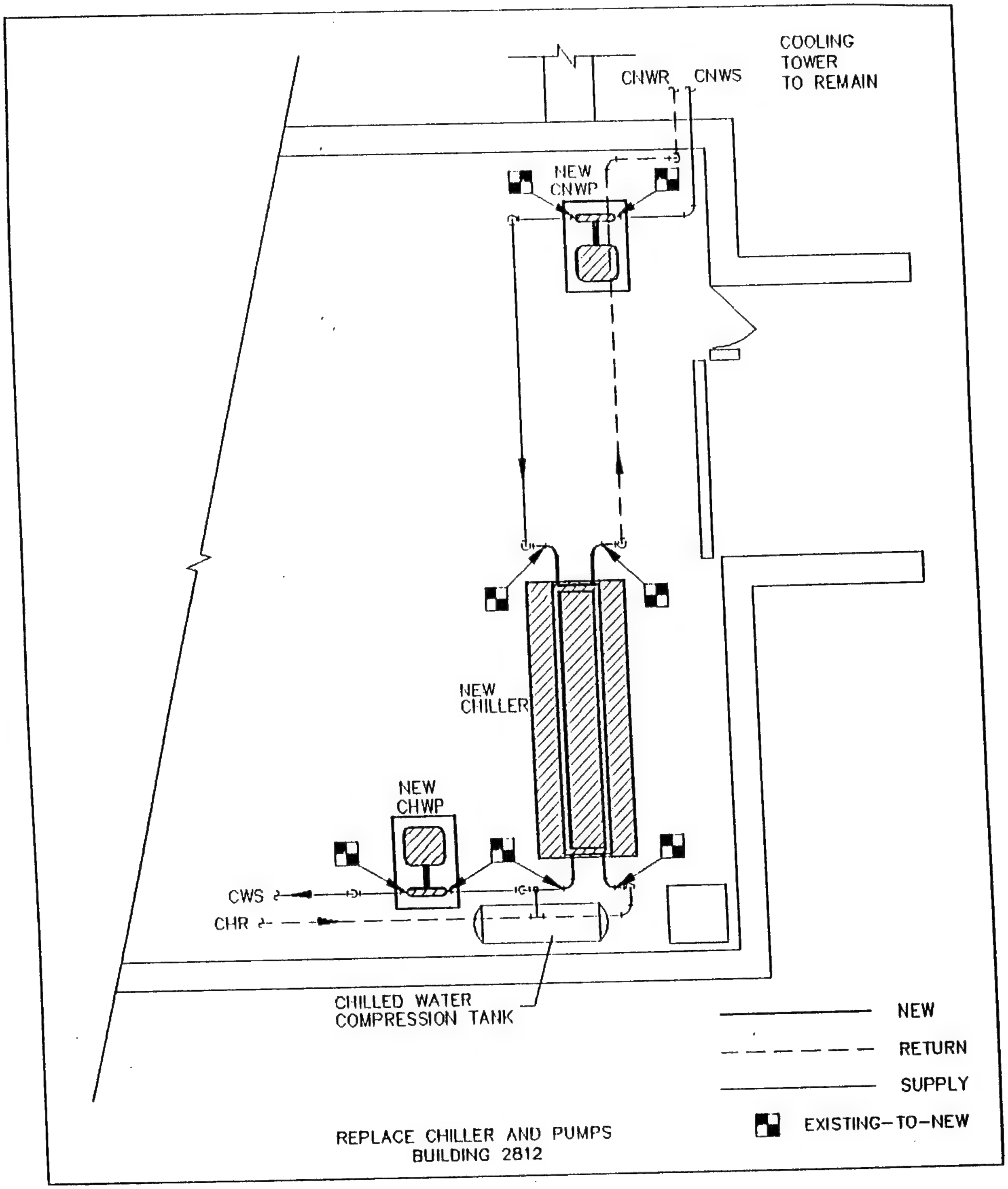


FIGURE 8-12. MECHANICAL ROOM LAYOUT, CENTRAL PLANT 2812

8.1.5 Project 5 - Comparison of Local HW Boiler in Area 3400 Barracks Versus Central Heating Plant in Building 3442

This analysis compares the energy consumption and construction costs of installing local modular, high efficiency hot water boilers in each building versus constructing a new central heating plant addition to the existing central cooling plant in Building 3442. The buildings evaluated are listed in Table 8-1 below.

TABLE 8-1
BUILDING LIST

BUILDING NUMBER	BUILDING DESCRIPTION
2470	Barracks with Mess Hall
3411	Barracks with Mess Hall
3413	Barracks with Mess Hall
3415	Barracks with Mess Hall
3417	Barracks with Mess Hall
3419	Barracks with Mess Hall
3422	Barracks with Mess Hall
3424	Barracks with Mess Hall
3426	Barracks with Mess Hall
3428	Barracks with Mess Hall
3430	Barracks with Mess Hall
3440	Barracks with Mess Hall
2471	Barracks without Mess Hall
3412	Barracks without Mess Hall
3414	Barracks without Mess Hall
3416	Barracks without Mess Hall
3418	Barracks without Mess Hall
3420	Barracks without Mess Hall
3421	Barracks without Mess Hall
3423	Barracks without Mess Hall
3425	Barracks without Mess Hall
3427	Barracks without Mess Hall
3429	Barracks without Mess Hall

A comparison of both case studies reveals the total life cycle cost for a 25-year period of installing local modular, high efficiency HW boilers in each building would be significantly better than constructing a new central heating plant addition to Building 3442. The life cycle costs for both case studies are:

- Local HW boilers $4,606,271
- Central heating plant $5,864,140

8.1.5.2 Construction of New Central Heating Plant for Barracks

Premise:
This case study proposes to remove existing steam boilers in the barracks and construct a central heating plant addition to the central cooling plant, Building 3442. Building 3442 will house three large HTHW boilers and three pumps. The proposed central heating plant will provide heating through a new hot water distribution system, which is connected to the barracks listed in Table 8-1, page 8-18. HTHW to LTHW converters would be used in each building, with associated pumps and equipment.

The central heating plant will have the following new equipment:

- 3 boilers (10 MMBtuh each)
- 3 HTHW pumps
- Associated expansion tanks and equipment.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this case study. The computer simulation was based on installing new central boilers for the barracks. The building heating consumption and heating peaks were added, along with distribution losses, to determine the new central heating plant loads.

See Appendix N for the computer simulation output.

Results:

Annual Electricity Consumption (kWh):	78,000
Annual Natural Gas Consumption (MMBtu):	75,555
Analysis Period:	25 Years
Total Utility Cost:	$3,877,413
Estimated Construction Cost:	$1,986,727
Total Life Cycle Cost:	$5,864,140

8.2 SUMMARY

Of the four projects for which a complete life cycle analysis was performed, only one is economically viable for ECIP funding, with an SIR greater than 1.0. The project recommended for implementation is Project 3 - Replacement of boilers 1 and 2 in Central Plants 2812 and 5900; this project has an SIR of 3.26 and a simple payback of 5.4 years.

The evaluation of Project 5 concluded the life cycle of replacing existing steam boilers in barracks with modular, high efficiency HW boilers is less than constructing a new central heating plant for surrounding barracks. The Life Cycle Cost for both case studies are:

- $4,606,000 for modular, high efficiency HW boilers in barracks.
- $5,864,000 for construction of new central heating plant.

8.1.5.1 Replacement of Existing Boilers in Barracks

Premise:
This case study proposes to replace existing steam boilers in each barracks with modular, high efficiency HW boilers.

The existing boilers are old and need to be replaced. New, high efficiency boilers will reduce the energy used to heat the barracks.

Each barracks will have two new hot water boilers and two new hot water pumps.

Basis for Analysis:
The PC-CUBE energy simulation program was used to analyze this case study. The computer simulation was based on new, high efficiency, modular HW boilers. Two types of barracks were evaluated: barracks with a mess hall and barracks without a mess hall, as listed in Table 8-1 on page 8-18. The energy consumption for the two types of buildings was multiplied by the number of buildings for each type.

See Appendix N for the computer simulation output.

Results:

Annual Natural Gas Consumption (MMBtu):	73,543
Analysis Period:	25 Years
Total Utility Cost:	$3,762,342
Estimated Construction Cost:	$843,929
Total Life Cycle Cost:	$4,606,271

SECTION 9.0

SUMMARY OF FINDINGS AND RECOMMENDATIONS

9.1 SUMMARY OF FIELD SURVEY FINDINGS

A field survey was completed in which the nine central plants were tested to determine the efficiency, condition, and operation of the plants. Overall, 18% of all boilers had problems and 68% of all chillers had problems. Of the 28 boilers and 19 chillers surveyed and tested, the following conditions were noted:

- Central Plant 730: chiller 4 was not operational; boiler 1 has a problem with soot, which indicates incomplete combustion.
- Central Plant 914: the new chiller would develop only 33% of rated capacity without surging; the automated control system was not functional. The poor design of the common breaching on the four boilers causes soot on boilers 3 and 4.
- Central Plant 2812: no special problems were noted.
- Central Plant 3442: heavy deposits were noted on the cooling tower; the central plant has an automated control system which was not being used.
- Central Plant 4701: chillers are in need of major repair or replacement; the high pressure steam boilers are old but seem to be in good operating condition.
- Central Plant 5676: the chiller had a high pressure drop across the evaporator; the two hot water boilers may require major repair or replacement.
- Central Plant 5678: the chiller surged with a heavy cooling load.
- Central Plant 5900: the only major concern is the cooling tower on chiller 1, which will not provide adequate heat rejection for the chiller.
- Central Plant 6003: chiller 1 was not operational; chillers 2 and 3 surged.

9.2 CHILLERS AND BOILERS DATA

Table 9-1 on pages 9-3 and 9-4 lists chillers and boilers surveyed and their sizes, along with the tested chiller efficiencies, tested boiler efficiencies, and the tested boiler percent excess air. Chiller efficiencies ranged from 0.61 kW per ton to 1.53 kW per ton. Boiler efficiencies ranged from 67% to 82%. Chiller efficiency ranges from 0.6 to 0.8 kW per ton are considered satisfactory. Boiler efficiency ranges from 77% to 82% are considered satisfactory.

TABLE 9-1
MAJOR CENTRAL PLANT EQUIPMENT

CENTRAL PLANT	BOILER NO.	BOILER SERVICE	BOILER EFF.	BOILER MFG	BOILER (MMBtuh	CHILLER	TESTED NO.	CHILLER (kW/ton)	CHILLER MFG(Tons)
730	1	STEAM	NA	KEWANEE	7.75	1	0.89	TRANE	800
	2	STEAM	81.4%	KEWANEE	7.75	3	0.74	TRANE	320
	3	STEAM	81.7%	KEWANEE	7.75	4	N/A	TRANE	320
	4	STEAM	81.5%	KEWANEE	2.66				
914	1	STEAM	82.0%	BRUNHAM	1.61	1	1.07	TRANE	400
	2	HW	77.4%	RAY-PAK	1.61				
	3	HW	77.9%	AMERICAN STANDARD	1.92				
	4	HW	74.4%	AMERICAN STANDARD	1.92				
2812	1	STEAM	79.7%	FEDERAL BOILER CO	1.80	1	0.81	CARRIER	170
	2	HW	71.5%	THERMO-PAK	3.95				
	3	HW	74.0%	THERMO-PAK	3.95				
3442	NONE					1	0.68	TRANE	600
	NONE					2	0.62	TRANE	600
4701	1	STEAM	79.2%	BIRCHFIELD	11.00	1	1.14	CARRIER	305
	2	STEAM	NA	BIRCHFIELD	11.00	2	0.97	CARRIER	305
	3	STEAM	79.2%	BIRCHFIELD	11.00				

N/A - Not available because of equipment problems.

TABLE 9-1
MAJOR CENTRAL PLANT EQUIPMENT (Concluded)

CENTRAL PLANT	BOILER NO.	BOILER SERVICE	BOILER EFF.	BOILER MFG	BOILER (MMBtuh)	CHILLER NO.	TESTED (kW/Ton)	CHILLER MFG	CHILLER (Tons)
5676	1	HW	75.1%	AMERICAN STANDARD	2.44	1	1.47	CARRIER	170
	2	HW	71.4%	AMERICAN STANDARD	2.44				
5678	1	HW	67.5%	BRUNHAM	2.27	1	0.71	TRANE	190
	2	HW	73.3%	BRUNHAM	2.27				
5900	1	HTHW	70.9%	INTERNATIONAL	10.00	1	0.92	CARRIER	400
	2	HTHW	73.2%	INTERNATIONAL	10.00	2	0.94	WESTINGHOUSE	400
	3	HTHW	80.8%	HERCULES	9.70	3	0.85	CARRIER	400
	4	HTHW	79.6%	HERCULES	9.70	4	0.94	MCQUAY	450
	5	HTHW	79.2%	INTERNATIONAL	8.00	5	0.85	CARRIER	400
	6	HTHW	80.8%	INTERNATIONAL	11.20				
6003	1	STEAM	82.3%	KEWANEE	11.72	1	NA	TRANE	400
	2	STEAM	79.8%	YORK SHIPLEY	11.72	2	NA	TRANE	450
	3	STEAM	NA	KEWANEE	11.72	3	NA	TRANE	450

N/A - Not available because of equipment problems.

9.3 ENERGY CONSERVATION OPPORTUNITY (ECO) ANALYSIS

The following method was used to perform the economic analysis for the central plants:

- Determine the current annual energy consumption as the baseline for evaluating ECOs on a plant-by-plant basis.
- Estimate the utility and maintenance usage for technically viable ECOs.
- Calculate the utility and maintenance savings or costs for an ECO by comparing the usage with the baseline estimate.
- Prepare a cost estimate for the ECO modification.
- Perform a life cycle cost analysis of the ECO.

Table 9-2 on page 9-6 lists the ECOs evaluated. Each individual ECO was evaluated as a stand-alone project. Interrelationships between individual ECOs were not taken into consideration. All of the individual ECOs determined to be technically feasible were evaluated for utility savings. The technically feasible individual ECOs are listed, by central plant, on Table 9-3, starting on page 9-7. The table provides the predicted annual energy savings (type and amount), annual dollar savings, construction costs, and life cycle economics, including savings-to-investment ratio (SIR) and simple payback.

Table 9-4 on page 9-12 lists individual ECOs evaluated by central plant. Table 9-5, beginning on page 9-13, lists the individual ECOs rejected because they were not technically feasible or were not applicable because of the condition of the plant.

A total of 81 individual ECOs were determined to be technically feasible; these were evaluated for potential utility savings. Of the individual ECOs evaluated, 26 projects had an SIR greater than 1.0 (see Table 9-3 on page 9-7). Those ECOs having an SIR of 1.0 and greater are by definition economically feasible. The total estimated construction cost for the 26 projects is $1,127,328.

TABLE 9-2
ECO LIST

ECO NUMBER	ECO DESCRIPTION	SPECIAL PROJECT - CENTRAL PLANT NUMBER
1.	Install instrumentation to establish chiller plant load to improve the plant operations, thereby saving energy.	
2.	Control systems to match chiller capacity and characteristics with the load, thereby saving energy.	
3.	Renovate or replace chillers to improve chiller efficiency, thereby saving energy.	
4.	Install ice storage cooling system to reduce peak air conditioning electrical demand.	
5.	5(A) - Install two-speed cooling tower fans to reduce cooling tower electrical energy. 5(B) - Install variable-speed cooling tower fans to reduce cooling tower electrical energy.	
6.	Install high efficiency motors to save electrical energy.	
7.	Install instrumentation to establish boiler plant load to improve the plant operations, thereby saving energy.	
8.	Control systems to match boiler capacity and characteristics with the load, thereby saving energy.	
9.	Renovate or replace boilers to improve efficiency, thereby saving energy.	
10.	Install combustion controls to assure proper fuel-to-air ratio; increase combustion efficiency, thereby saving energy.	
11.	Install new high efficiency burners on boilers to increase combustion efficiency, thereby saving energy.	
12.	Install stack economizer or air preheater to recover heat from the boiler stack, thereby saving energy.	
13.	Install chilled water variable speed pumping to improve flow and pressure drop in the distribution system, saving electrical energy.	5900
14.	Install smaller pumps to match flow requirements, saving electrical energy.	730 & 4701
15.	Install a cogeneration, natural gas turbine engine, to generate electricity on-site, saving electrical demand and energy.	6003
16.	Install natural gas driven chillers to save electrical demand and energy.	2812
17.	Install electric boilers in buildings for summer DHW to shut down central plant in the summer, saving distribution loss and pumping energy.	730 & 2812

TABLE 9-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
730	1	129	243,000	0	829	$3,329	$2,766	$320	$5,620	9.6	0.9
	2	163	338,000	0	1,154	$4,631	$3,495	$1,077	$18,939	3.5	2.6
	3	22	2,000	0	7	$27	$472	$3,000	$6,330	-3.8	N/A
	4	712	0	0	0	$0	$15,268	$0	$192,000	0.9	12.6
	5(A)	0	17,441	0	60	$239	$0	$0	$14,890	0.2	59.3
	5(B)	0	18,709	0	64	$256	$0	$579	$10,180	-0.4	N/A
	6	41	85,430	0	292	$1,170	$879	$0	$50,297	0.5	23.3
	7	0	0	89	89	$260	$0	$255	$4,482	0.2	966.1
	10	0	0	108	108	$315	$0	$2,411	$29,654	-0.6	N/A
	14	0	144,560	0	493	$1,980	$0	$0	$12,809	1.9	6.2
	17	(121)	(48,800)	1,582	1,415	$3,951	($2,595)	$0	$38,431	1.2	27.0
914	3	93	130,000	0	444	$1,781	$1,994	$3,000	$3,165	2.2	3.9
	4	428	0	0	0	$0	$9,178	$0	$96,000	1.1	10.5
	5(B)	0	2,697	0	9	$37	$0	$361	$6,352	-0.6	N/A
	6	5	8,932	0	30	$122	$107	$0	$9,429	0.3	39.1
	7	0	0	11	11	$32	$0	$320	$5,620	-0.5	N/A

TABLE 9-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
914	8	0	0	44	44	$128	$0	$2,031	$33,847	-0.5	N/A
(Continued)	9	0	0	500	500	$1,460	$0	$3,000	$18,035	-0.5	N/A
2812	3	42	72,000	0	246	$986	$901	$3,000	$94,894	-0.2	N/A
	4	301	0	0	0	$0	$6,455	$0	$89,280	0.8	13.8
	5(A)	0	8,560	0	29	$117	$0	$0	$7,077	0.2	57.4
	5(B)	0	11,167	0	38	$153	$0	$298	$5,236	-0.4	N/A
	6	4	18,353	0	63	$251	$86	$0	$8,368	0.5	23.6
	7	0	0	21	21	$61	$0	$320	$5,620	-0.4	N/A
	8	0	0	307	307	$896	$0	$1,543	$27,128	-0.1	N/A
	9	0	0	621	621	$1,813	$0	$1,056	$6,012	2.2	8.0
	16	144	278,000	(1,498)	(549)	($566)	$3,088	$384	$444,584	0.0	185.0
	17	(176)	(726,000)	7,346	4,868	$11,504	($3,774)	$0	$181,078	1.3	22.3
3442	1	0	209,000	0	713	$2,863	$0	$228	$4,012	6.0	1.5
	2	0	281,000	0	959	$3,850	$0	$936	$16,449	1.6	5.4
	4	780	0	0	0	$0	$16,726	$0	$288,000	0.7	17.2
	5(B)	0	35,884	0	122	$492	$0	$597	$10,499	-0.1	N/A
	6	4	12,880	0	44	$176	$86	$0	$25,318	0.1	92.1

TABLE 9-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
4701	1	0	71,000	0	242	$973	$0	$320	$5,620	3.1	2.9
	2	0	178,000	0	608	$2,439	$0	$234	$16,929	1.2	7.3
	3	113	126,000	0	430	$1,726	$2,423	$3,000	$218,314	0.1	180.7
	4	583	0	0	0	$0	$12,502	$0	$132,000	1.1	10.6
	5(B)	0	17,453	0	60	$239	$0	$1,013	$17,808	-0.5	N/A
	6	3	4,605	0	16	$63	$64	$0	$18,176	0.1	136.1
	7	0	0	61	61	$178	$0	$463	$8,145	-0.3	N/A
	10	0	0	160	160	$467	$0	$1,799	$24,869	-0.5	N/A
	12	0	0	89	89	$260	$0	$0	$46,799	0.1	198.0
	14	0	50,401	0	172	$690	$0	$0	$21,168	0.4	29.2
5676	3	96	137,000	0	468	$1,877	$2,059	$3,000	$94,320	0.1	95.9
	4	250	0	0	0	$0	$5,361	$0	$40,800	1.5	7.6
	5(A)	0	4,100	0	14	$56	$0	$0	$4,296	0.2	72.8
	5(B)	0	4,970	0	17	$68	$0	$289	$5,076	-0.5	N/A
	6	4	24,287	0	83	$333	$86	$0	$4,797	1.1	10.9
	7	0	0	13	13	$38	$0	$0	$5,620	-0.5	N/A
	9	0	0	5,520	5,520	$16,118	$0	$0	$105,344	1.6	11.8

TABLE 9-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
5676	10	0	0	238	238	$695	$0	$1,799	$24,869	0.3	21.4
(continued)	12	0	0	718	718	$2,097	$0	$0	$31,635	1.3	14.0
5678	4	142	0	0	0	$0	$3,045	$0	$48,000	0.7	15.8
	5(A)	0	3,873	0	13	$53	$0	$0	$4,296	0.2	77.0
	5(B)	0	4,721	0	16	$65	$0	$289	$5,076	-0.6	N/A
	6	3	14,412	0	49	$197	$64	$0	$4,821	0.7	17.5
	7	0	0	11	11	$32	$0	$320	$5,620	-0.5	N/A
	8	0	0	272	272	$794	$0	$1,632	$28,699	-0.2	N/A
	9	0	0	14,980	14,980	$43,742	$0	$3,000	$105,344	2.4	7.6
	10	0	0	1,537	1,537	$4,488	$0	$1,799	$24,869	1.7	8.9
	12	0	0	196	196	$572	$0	$0	$31,635	0.3	52.6
5900	1	0	519,104	0	1,772	$7,112	$0	$319	$5,620	11.1	0.8
	2	9	539,430	0	1,841	$7,390	$193	$1,188	$20,887	2.8	3.1
	3	154	718,000	0	2,451	$9,837	$3,302	$3,000	$49,465	0.6	14.8
	4	1,890	0	0	0	$0	$40,529	$0	$504,000	0.9	12.4
	5(A)	0	15,915	0	54	$218	$0	$0	$8,154	0.3	35.6
	5(B)	0	21,175	0	72	$290	$0	$425	$7,469	-0.2	N/A

TABLE 9-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS ($)	ANNUAL DEMAND CREDIT ($)	ANNUAL MAINT. COST ($)	CONST. COST ($)	SIR	SIMPLE PAYBACK (YRS)
5900	6	28	42,400	0	145	$581	$600	$0	$58,343	0.2	47.0
(Continued)	7	0	0	161	161	$470	$0	$306	$5,377	0.6	31.2
	8	0	0	6,157	6,157	$17,978	$0	$2,745	$48,257	4.3	3.0
	9	0	0	7,241	7,241	$21,144	$0	$1,792	$12,685	20.5	0.6
	10	0	0	3,182	3,182	$9,291	$0	$4,247	$44,010	1.9	8.3
	12	0	0	6,389	6,389	$18,656	$0	$0	$140,396	2.5	7.2
	13	0	203,000	0	693	$2,781	$0	$2,507	$157,969	0.0	547.0
6003	1	0	215,000	0	734	$2,946	$0	$320	$5,620	5.3	1.7
	4	544	0	0	0	$0	$11,666	$0	$204,000	0.7	17.5
	5(A)	0	25,818	0	88	$354	$0	$0	$11,002	0.4	29.6
	5(B)	0	31,025	0	106	$425	$0	$570	$10,021	-0.2	N/A
	6	12	25,861	0	88	$354	$257	$0	$23,185	0.3	36.1
	7	0	0	67	67	$196	$0	$255	$4,482	0.0	N/A
	10	0	0	450	450	$1,314	$0	$1,187	$20,083	0.3	150.4
	15	417	977,000	(49,603)	(46,268)	($131,456)	$8,942	$3,000	NA		

TABLE 9-4
ECOs EVALUATED LISTED BY CENTRAL PLANT

ECO NO.	CENTRAL PLANT								
	730	914	2812	3442	4701	5676	5678	5900	6003
1	X			X	X			X	X
2	X			X	X			X	
3	X	X	X		X	X		X	
4	X	X	X	X	X	X	X	X	X
5(A)	X		X			X	X	X	X
5(B)	X	X	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X	X	X
7	X	X	X		X	X	X	X	X
8		X	X				X	X	
9		X	X			X	X	X	
10	X				X	X	X	X	X
11									
12					X	X	X	X	
13								X	
14	X				X				
15									X
16			X						
17	X		X						

TABLE 9-5
ECOs CONSIDERED NOT FEASIBLE

CENTRAL PLANT	ECO NO.	COMMENTS
730	8	No opportunity for boiler optimization.
	9	No opportunity for additional savings for boiler renovation.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.
914	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	5(A)	The cooling tower already has two-speed tower fans.
	10	These burners are non-modulating type burners. Oxygen trim will not work.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.
2812	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	10	These burners are non-modulating type burners. Oxygen trim will not work.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.
3442	3	No opportunity for more efficient chillers.
	5(A)	This cooling tower has four cells. It is not feasible to add two-speed control.

TABLE 9-5
ECOs CONSIDERED NOT FEASIBLE

CENTRAL PLANT	ECO NO.	COMMENTS
4701	5(A)	This cooling tower has four cells. It is not feasible to add two-speed control.
	8	No opportunity for boiler optimization.
	11	No high efficiency burners small enough for these boilers.
5676	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	11	No high efficiency burners small enough for these boilers.
5678	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	3	No opportunity for more efficient chillers.
	11	No high efficiency burners small enough for these boilers.
5900	11	No high efficiency burners small enough for these boilers.
6003	2	No opportunity for chiller optimization. Both chillers are the same size and efficiency.
	9	No opportunity for additional savings.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.

9.4 PROJECTS DEVELOPED

At the Interim Submittal review conference with Fort Sill DEH, the individual ECOs which were determined to be economically viable were reviewed. The individual ECOs were either grouped into projects or eliminated because of functional decision making. Five projects were developed from the individual ECOs. These projects were evaluated to determine if they were economically feasible for funding under the Energy Conservation Investment Program (ECIP). The five projects developed for further analysis included:

- Project 1 - Control project for Central Plants 730, 5900, and 6003: Install microprocessor-based instrumentation and controls to remotely monitor and control mechanical equipment in central plants. The control system monitors central plant loads and selects appropriate equipment to match the equipment capacity with the load, thereby saving energy.

- Project 2 - Central heating plant project and control project for Buildings 5676 and 5678: Expand existing central plant to provide heating. Boilers and pumps are replaced to improve efficiency, thereby saving energy.

- Project 3 - Replacement of boilers 1 and 2 in Central Plants 2812 and 5900: Replace boilers 1 and 2 in Central Plants 2812 and 5900 to improve boiler efficiency, thereby saving energy.

- Project 4 - Replacement of chiller in Central Plant 2812 with a higher efficiency chiller: Replace chiller in Central Plant 2812 with a high efficiency chiller matched to the central plant loads, thereby saving energy.

- Project 5 - Comparison of local hot water boiler in each barracks versus central heating plant project, 3400 Area: Compare replacement of steam boilers with high efficiency modular hot water boilers in barracks versus constructing a central heating plant to provide hot water.

Table 9-6 on page 9-16 summarizes the economics of the projects listed above. Table 9-7 on page 9-16 demonstrates annual potential energy conserved and cost savings. The evaluation results indicate:

- Projects 1, 2, and 4 would not qualify for ECIP funding.

- Project 3 would qualify for ECIP funding.

- The life cycle cost of individual hot water boilers in each barracks is less than a new central plant.

TABLE 9-6
ECONOMIC SUMMARY OF PROJECTS DEVELOPED

PROJECT NUMBER	ECONOMIC LIFE (YRS)	CONSTRUCTION COST ($)	ANNUAL ENERGY SAVINGS			ANNUAL DOLLAR SAVINGS			SIR	SIMPLE PAYBACK (YRS)
			PEAK DEMAND (kW)	ELECTRICAL (kWh)	NAT. GAS (MMBtu)	DEMAND ($)	ELECTRICAL ($)	NAT. GAS ($)		
1	15	608,539	164	1,507,208	7,682	3,517	20,649	22,431	0.50	32.8
2	25	309,222	0	0	2,956	0	0	8,632	0.49	58.0
3	25	493,543	14	122,000	29,160	300	1,671	85,819	3.84	6.2
4	25	208,111	23	78,000	0	493	1,069	0	0.00	N/A
5	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

The results of Life Cycle Cost for both case studies for Project 5 indicate:

- $4,606,271 for replacement of modular hot water boilers in each barracks.
- $5,864,140 for construction of new central heating plant for all 3400 Area barracks.

TABLE 9-7
ANNUAL POTENTIAL ENERGY CONSERVED AND COST SAVINGS

ITEM	PEAK ELECTRICAL DEMAND	ELECTRICAL ENERGY	NATURAL GAS
CURRENT POSTWIDE CONSUMPTION	287,633 kW	151,843,500 kWh	1,026,161 MMBtu
CONSUMPTION WITH PROJECT IMPLEMENTED (PROJECT 3)	287,619 kW	151,721,500 kWh	995,942 MMBtu
PERCENT SAVING	0.005 %	0.08 %	3.0 %
DOLLAR SAVING	$300	$1,670	$88,240

9.5 PRESENT ENERGY CONSUMPTION

Historical energy usage data at Fort Sill was evaluated to compare savings figures with actual consumption.

Electrical energy consumption, demand, and costs for FY90 are tabulated in Table 9-8 on page 9-18. The monthly electrical consumption for FY90 varies from a minimum of 9,049,600 kWh in November, to a maximum of 18,376,344 kWh in August. The monthly electrical consumption is illustrated graphically in Figure 9-1 below.

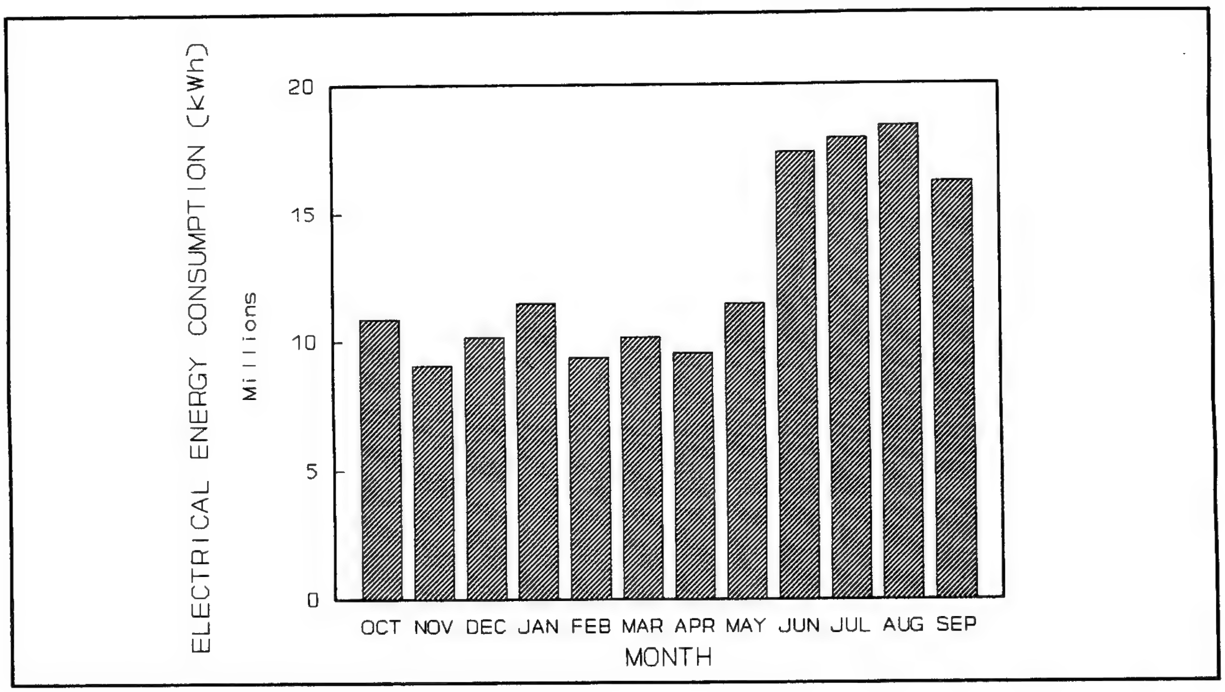


FIGURE 9-1, MONTHLY ELECTRICAL CONSUMPTION

TABLE 9-8
ELECTRICAL USAGE AND BILLING

SERVICE MONTHS FY 90	ELECTRICAL ENERGY TOTAL (kWh)	FEDERAL GENERATED ENERGY (kWh)	THERMAL ENERGY (kWh)	ACTUAL DEMAND (kW)	FIRM CAPACITY DEMAND (kW)	THERMAL DEMAND (kW)	FEDERAL GENERATED ENERGY COST ($)	THERMAL ENERGY COST ($)	FEDERAL GENERATED DEMAND COST ($)	THERMAL DEMAND COST ($)	TOTAL ELECTRICAL COST [1] ($)
OCT	10,859,520	9,758,900	1,100,620	20,815.2	36,700	35,641	$39,035.60	$26,965.19	$108,632	$63,690.82	$238,323.61
NOV	9,049,600	4,630,583	4,419,017	17,530.8	36,700	35,641	$18,522.33	$105,406.81	$108,632	$63,690.82	$296,251.96
DEC	10,146,864	0	10,146,864	18,933.6	36,700	35,641	$0.00	$241,251.84	$108,632	$63,690.82	$413,574.66
JAN	11,481,680	7,041,950	4,439,730	18,236.4	36,700	35,641	$28,167.80	$94,339.83	$108,632	$63,690.82	$294,830.45
FEB	9,377,648	9,377,648	0	17,858.4	36,700	35,641	$37,510.59	$0.00	$108,632	$63,690.82	$209,833.41
MAR	10,158,176	10,158,176	0	17,808.0	36,700	35,641	$40,632.70	$0.00	$108,632	$63,690.82	$212,955.52
APR	9,527,263	9,527,263	0	17,740.8	36,700	35,641	$38,109.05	$0.00	$108,632	$63,690.82	$210,431.87
MAY	11,453,400	11,453,400	0	25,880.4	36,700	35,641	$45,813.60	$0.00	$108,632	$63,690.82	$218,136.42
JUN	17,358,264	17,358,264	0	33,843.6	36,700	35,641	$69,433.06	$0.00	$108,632	$63,690.82	$241,755.88
JUL	17,884,272	17,884,272	0	33,339.6	36,700	35,641	$71,537.09	$0.00	$108,632	$63,690.82	$243,859.91
AUG	18,376,344	10,444,935	7,931,409	33,705.0	36,700	35,322	$41,779.74	$199,704.95	$108,632	$63,120.41	$413,237.10
SEP	16,170,504	5,437,224	10,733,280	31,941.0	36,700	33,844	$21,748.90	$240,071.27	$108,632	$60,478.51	$430,930.68
TOTAL	151,843,535	113,072,615	38,770,920	287,633			$452,290	$907,740	$1,303,584	$760,507	$3,424,121

Natural gas consumption for FY89 is tabulated in Table 9-9 below. The monthly natural gas consumption for FY89 varies from a minimum of 21,739 MMBtu in August to a maximum of 222,094 MMBtu in February. The monthly natural gas consumption is illustrated graphically by Figure 9-2 on page 21.

TABLE 9-9
NATURAL GAS CONSUMPTION - FY89

Month	MMBtu Consumption
October	38,562
November	108,070
December	163,565
January	173,196
February	222,094
March	135,771
April	50,266
May	29,267
June	26,329
July	26,000
August	21,739
September	31,302
Total	1,026,161

Table 9-10 on page 9-20 lists the estimated annual baseline energy consumption and demand of the nine central plants evaluated in this study.

TABLE 9-10
ANNUAL ENERGY CONSUMPTION OF CENTRAL PLANTS

CENTRAL PLANT	PEAK ELECTRICAL DEMAND (kW)	ANNUAL ELECTRICAL CONSUMPTION (kWh/yr)	ANNUAL NAT. GAS CONSUMPTION (MMBtu/yr)	TOTAL ENERGY CONSUMPTION (MMBtu/yr)
730*	732	1,175,000	27,469	31,479
914	286	563,000	13,852	15,774
2812*	93	386,000	21,453	22,770
3442	590	1,340,000	0	4,573
4701	396	306,000	9,596	10,640
5676*	165	200,000	4,780	5,463
5678*	146	190,000	5,639	6,287
5900*	1,781	4,632,678	79,219	95,030
6003*	563	1,861,000	42,402	48,754
TOTAL		10,653,678	204,410	240,770

* Energy consumption has been revised for Prefinal Submittal; assumed no EMCS.

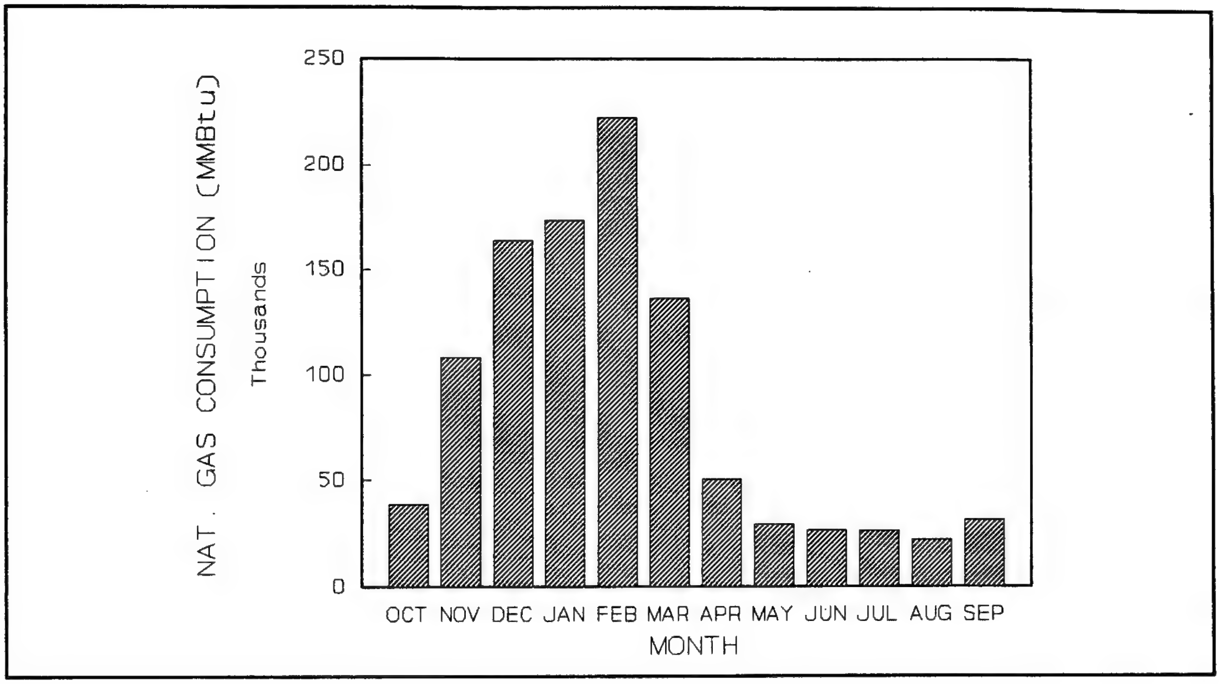


FIGURE 9-2, MONTHLY NATURAL GAS CONSUMPTION

9.6 CENTRAL PLANT SPECIAL CONSIDERATIONS

Several central plants were evaluated to determine if excess capacity exists which can be used for heating and cooling requirements in other buildings. The findings of this review are noted:

- Central Plant 730 has 371 tons of excess cooling capacity.
- Central Plant 1653 has 1.47 MMBtuh of excess heating capacity.
- Central Plant 3442 has 171 tons of excess cooling capacity.
- Central Plant 6003 has 19.03 MMBtuh of excess heating capacity and 535 tons of excess cooling capacity.

Central plants were reviewed as to the technical merits of consolidating central plants. The findings of this review included:

- Central Plants 5676 and 5678: The central plants in these two buildings are in close proximity, allowing a relatively easy installation.

- Plant 3442 addition: A project to add a central high temperature hot water (HTHW) boiler plant to Building 3442 was previously evaluated under a fort-wide energy study. This project is currently programmed for construction with a barracks upgrade project.

- Central Plant 914: The central heating plants in Buildings 900, 912, 913, and 914 are in close proximity, allowing a relatively easy installation (the chiller plants are already connected); however, unless there is a need to replace the existing equipment because of age and condition, it would be difficult to economically justify consolidation of the heating plants.

- Area 800, central energy plant: A central plant for the 800 area to displace existing plants in Buildings 445, 462, 730, 913, 1603, and 1653 was evaluated under a fort-wide energy study. The economics of this project were low, and Fort Sill has not programmed this project.

9.7 CENTRAL PLANT OPERATIONAL RECOMMENDATIONS

The operational items noted which will provide Fort Sill with energy savings at low cost or no cost include:

- Maintain and review log data on a periodic basis for all chillers and boilers to track potential changes in operating conditions which may indicate problems and inefficient operation.

- Use existing microprocessor-based controls on chiller plants as effectively as possible. If Fort Sill has insufficient documentation and training, efforts should be made to obtain more from the manufacturer.

- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as can be safely used by the refrigeration system, or as low as can be provided under the outdoor air conditions. This applies to all central chiller plants.

- The lower basin of the cooling tower above the two-cell partition should be filled to eliminate cross-flow between cells. If only one fan is running, when the water level is below the partition, air is pulled through the second fan opening, and not through the cooling tower media. As a result, one fan runs longer because the air is not flowing across the condenser water. This applies to Central Plants 730, 914, and 3442.

- Various operating conditions of hot water temperatures and hot water pumping from Central Plant 730 should be tested. To reduce distribution losses, hot water supply temperatures should be maintained at a minimum. To lower pumping requirements, the minimum number of water pumps should be run to meet the heating load. This applies to Central Plants 730, 914, 5676, 5678, and 5900.

- To maintain the longer boiler life associated with lower boiler temperatures and pressures, operators should also try lowering the boiler steam pressure from 10 psig to less (2 psig to 5 psig). This applies to Central Plants 730, 914, and 2812.

- Operate the minimum number of chillers, boilers, and pumps required to meet the cooling and heating loads. In many cases, extra chillers, boilers, and pumps are being operated unnecessarily, wasting energy. The following specific operating procedures for each central plant are recommended as a guide for the operator.

9.8 INDIVIDUAL CENTRAL PLANT DESCRIPTIONS AND OPERATIONAL RECOMMENDATIONS

9.8.1 Central Plant 730

Chillers:

Central Plant 730 has two chillers, one 300 tons and one 800 tons, which are operational. The chillers in Central Plant 730 could be run more efficiently if additional attention is directed at operating those chillers and pumps most suited to fit the estimated load. No instrumentation is present to inform operators of the size of the load currently on the plant.

Boilers:

Three of the four boilers in Central Plant 730 operate during the winter to meet heating and DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

9.8.2 Central Plant 914

Chillers:

Central Plant 914 has one 400 ton chiller which, although new, is not operating at rated capacity or specified efficiency. (See survey information discussed in Section 2.2.2 on page 2-11 of this submittal.) The measured efficiency was 1.23 kW per ton, versus the design rating of 0.65 kW per ton to 0.7 kW per ton. The pressure drop across the evaporator was much higher than the design; EMC noted a drop of 23 foot head of water, compared to a maximum design of 10 foot head of water. This indicates a potential problem with clogged tubes (fouling). The same problem was experienced with the pressure drop across the condenser; however, this problem is not as severe. For the condenser, EMC measured the pressure drop at 13.8 foot head of water, compared to a design pressure drop of 10 foot head of water. Cleaning the tubes, as well as diagnosing and

solving this problem will assure there is adequate capacity for the cooling load, and will also save energy because of higher efficiencies.

Although a microprocessor-based control system is available for this central plant, the chiller controls were set on manual when surveyed.

Boilers:

Central Plant 914 has four boilers, three of which operate during the winter to meet the heating load and one which operates year-round to meet DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

Boilers 3 and 4 in Central Plant 914 produce soot during firing, and soot is removed on a regular basis. This is apparently caused by the unsatisfactory arrangement of individual outlets into the common breaching. Another possible cause is the forced draft burner of the boiler nearest the stack, which may create a positive pressure in the breaching, thus eliminating the stack draft from the three atmospheric burners in this central plant. In order to avoid future problems with soot buildup, the root of the problem must be corrected, rather than continually removing soot.

9.8.3 Central Plant 2812

Boilers:

Central Plant 2812 has three boilers, two of which operate during the winter to meet the heating and DHW loads, and one which operates year-round to provide steam for the mess hall, Building 2811. No master boiler control is present to control staging of the boilers.

9.8.4 Central Plant 3442

Chillers:

Central Plant 3442 has two 600 ton chillers. Although a microprocessor-based control system is available for this plant, the chiller controls were set on manual when surveyed. The telephone line connecting the central plant microprocessor-based controls with the DEH operator console had been removed.

Fort Sill would benefit if communication command were to reinstall a telephone line to provide remote monitoring of the central plant. In addition, the microprocessor-based control system should be tested and made operational to optimize chiller usage. The chillers in Central Plant 3442 will be run more efficiently if additional attention is directed at those chillers and pumps most

suited to fit the estimated load. No instrumentation is present to inform operators of the size of the load currently on the plant.

9.8.5 Central Plant 4701

Chillers:

Central Plant 4701, which serves the hospital, has two 275 ton chillers. One of the chillers operates at very poor efficiency (1.31 kW per ton), while the other chiller surges. Chiller 1 requires constant refrigeration charging. Diagnosing and solving the problems will assure adequate capacity for the cooling load and will also save energy by increasing efficiency.

Because of the critical requirements of the hospital, the operators should continue to operate the chillers as needed to maintain environmental conditions. Based on the efficiency of the two chillers, it is recommended the operators use chiller 2 first. When the hospital operations are moved to the new facility and Building 4700 no longer has critical requirements, the operators should attempt to reset chilled water temperatures to save energy.

Boilers:

Central Plant 4701 has three boilers, two of which operate during the winter to meet the heating and DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

When Building 4700 is converted to an administrative building and there is no need for high pressure steam, the central plant will not require an operator in attendance. Additionally, it is anticipated the steam pressure can be reduced from 100 psig to less than 15 psig, while continuing to maintain satisfactory capacity with the associated longer life of a boiler operating at lower pressures and temperatures.

9.8.6 Central Plant 5676

Chillers:

Central Plant 5676 has one 170 ton chiller which operates at 1.53 kW per ton, very poor efficiency when compared to the chiller in Central Plant 5678, which operates at 0.73 kW per ton. Diagnosing and solving the problem with this chiller will assure adequate capacity for the cooling load, and will also save energy because of higher efficiency.

Additional operational action items:

- The flow ports on the upper basin of the cooling tower are clogged with dirt and debris, causing the condenser water to overflow. These ports should be cleaned to assure proper flow across the cooling tower media.

Boilers:

Both boilers in Central Plant 5676 operate during the winter to meet the heating load. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

9.8.7 Central Plant 5678

Chillers:

The 190 ton chiller in Central Plant 5678 surged when it was tested above 4° delta T. Diagnosing and solving the problem with this chiller will assure adequate capacity for the cooling load, and also save energy because of higher efficiencies.

Boilers

The two boilers in Central Plant 5678 operate during the winter to meet heating and DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

9.8.8 Central Plant 5900

Chillers:

Central Plant 5900 has five chillers, including four 400 ton units and one 450 ton unit. Efficiencies range from 0.83 kW per ton to 0.94 kW per ton. Only one mechanical problem was noted with the chillers: the cooling tower on chiller 1 seems to be undersized and not able to provide adequate condenser cooling capacity.

The chillers in Central Plant 5900 will be run more efficiently if additional attention is directed at operating the chillers and pumps most suited to fit the estimated load. No instrumentation is present to inform operators of the size of the load currently on the central plant.

Additional operational action items:

- No extra chilled water pumps should be run without an associated chiller.
- The differential pressure controller and control valves on the discharge of the plant should be checked to determine the current operating condition of each.

Boilers:

The six HTHW boilers in Central Plant 5900 operate during the winter to meet the heating and DHW loads. No master boiler control is present to control staging of the boilers. When the last boiler was added to the central plant, the main HTHW flow meter in the central plant was not changed to measure the new maximum flow capacity from the central plant. As a result, operators cannot determine the heating capacity of the central plant. The main flow meter should be replaced and calibrated to match the maximum load flow condition from the central plant; the chart recorders should be adjusted to register the flows. With knowledge of the heating loads on the central plant, the boilers can be run more efficiently to meet the loads, thus minimizing standby losses and saving energy.

9.8.9 Central Plant 6003

Chillers:

Central Plant 6003 has two 450 ton chillers which are operational and one 400 ton chiller which is not operational. The chillers in Central Plant 6003 will be run more efficiently if additional attention is directed at operating the chillers and pumps most suited to fit the estimated load. Although a sequence panel exists to operate the two chillers in a lead-lag manner based on current limits, the sequence panel was not used. Chiller 2 is experiencing mechanical problems. Cleaning the tubes and diagnosing and solving the mechanical problems will assure adequate capacity for the cooling load and will save energy by increasing efficiency.

Boilers:

Central Plant 6003 has three boilers, two of which operate during the winter to meet the heating and DHW needs. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

9.9 REFRIGERANTS

Under the Clean Air Act of 1990, the United States Congress adopted an accelerated phase-out schedule, cutting chlorofluorocarbon (CFC) production to 50% of the 1986 levels by 1995 and to 15% by 1997. This country's CFC production will end by the year 2000. Because most of the chillers at Fort Sill now use CFC-11 or CFC-12, the required changes in CFC production will have a major impact.

A number of economic factors must be considered in determining whether to purchase new equipment or to convert existing chillers. These factors include:

- Estimated equipment life
- Equipment current performance
- Operating requirements
- Cost of new equipment
- Cost of equipment room modifications
- Maintenance and refrigerant costs
- Utility costs.

The EPA forecasts the cost of CFC-11, which is currently $3.50 to $4 per pound, will rise to $12 per pound by 1999. Thus, a 1,000-pound charge costing around $4,000 today would be $12,000 in 1999. The cost today for HCFC-123 is about double the cost of CFC-11; HCFC-123, however, is trending downward, while CFC-11 is trending upward. Du Pont predicts a pricing crossover will occur sometime in 1992 or 1993.

If a system now operating on CFC has marginal capacity, converting to a new refrigerant may leave it short of capacity or with poor performance. The manufacturers are currently testing and developing performance charts for HCFC conversions. When this information is complete, the government should make a comprehensive evaluation to determine how the new refrigerant will affect capacity and efficiency and what modifications are needed to achieve optimum performance.

9.10 OTHER RECOMMENDATIONS

- In the future, Fort Sill should review third-party financing (TPF) as a possible alternative for central plant renovations, additions, and operations.

- In the future, Fort Sill should develop operational procedures for each central plant to optimize plant operations and conserve energy. Each central plant operator should be given a bound copy of the operational procedures, engineering look-up tables, and test instrumentation, along with formal training in the importance of central plant maintenance and operations on energy conservation and utility cost savings.

- In the future, Fort Sill should train a single specialized maintenance crew to test and adjust boilers with a flue gas analyzer, rather than having these procedures performed by each central plant operator.

APPENDIX A

SCOPE OF WORK

SCOPE OF WORK SUMMARY
ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS, Fort SILL, OKLAHOMA

ITEM NO.	SOW PAGE	SOW SECTION	DESCRIPTION	REPORT SECTION
1	1	1.1	Survey the boilers to determine their efficiency.	2.0
2	1	1.3	Identify and list all ECOs considered.	4.0
3	1	1.3	Identify low cost or no cost ECOs.	6.0
4	1	1.6	Prepare report.	-
5	1	2.1	Include in the study the results of previous studies concerning boiler and chiller plants.	5.0
6	2	2.5	Determine if ECOs are technically and economically feasible.	4.0
7	2	2.5	Combine ECOs into larger packages for ECIP or MCP funding.	8.0
8	2	2.6	List and prioritize, by SIR, projects which qualify for ECIP funding.	Table 7-2
9	2	2.7	Prioritize, by SIR, feasible non-ECIP projects.	8.0
10	4	5.1	Develop life cycle cost analysis summary sheets for ECIP projects.	Appendix D
11	4	5.1	Provide original backup calculations from previous studies.	Appendix G and H
12	5	5.2	Develop life cycle cost analysis summary sheets for non-ECIP projects.	Appendix D
13	6	5.3	Document nonfeasible ECOs in the report.	4.0
14	6	7.1.1	Conduct boiler efficiency tests.	Appendix F, Survey Notes
15	6	7.1.2	Conduct chiller efficiency tests.	Appendix E, Survey Notes
16	7	7.2.2	Investigate existing local controls and incorporate into EMCS.	4.0
17	7	7.2.3	Review, document, and evaluate operation and maintenance practices.	2.0 and 6.0

SCOPE OF WORK SUMMARY (Concluded)
ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS, Fort SILL, OKLAHOMA

ITEM NO.	SOW PAGE	SOW SECTION	DESCRIPTION	REPORT SECTION
18	7	7.3	Thoroughly evaluate and document all potential ECOs which are not eliminated.	Appendix D
19	8	7.6	Prepare a comprehensive report.	Interim Submittal
20	10	7.6.1	Interim submittal - include analyses performed to date and results of field survey.	Interim Submittal
21	10	7.6.1	Interim submittal - include copies of the Scope of Work and any modifications.	Appendix A
22	10	7.6.1	Interim submittal - provide a narrative summary.	Executive Summary
23	10	7.6.1	Interim submittal - include copies of field survey forms.	Appendix E and F
24	10	7.6.2	Prefinal submittal - document the integrated aspects of the study.	8.0
25	10	7.6.2	Prefinal submittal - include an order of priority, by SIR, for the recommended ECOs.	8.0
26	11	7.6.2	Prefinal submittal - include an executive summary per Annex D.	Executive Summary
27	11	7.6.2	Prefinal submittal - list all projects and ECOs developed in the study.	7.0 and 8.0
28	11	7.6.3	Final Report - incorporate revisions and corrections resulting from comments.	Final Report
29	11	8.2	Identify operational items noted in the study which will effect energy conservation.	Section 6.0
30	6	7.1.1 & 7.1.2	Use metering equipment with the proper accuracies and calibration.	Appendix E
31	A-17	-	Present overview of the impact on changing refrigerants to environmentally safe refrigerants.	Section 5.0
32	-	-	Plants included in study: 730, 914, 2812, 4701, 5676, 5678, 5900, 6003.	-

SCOPE OF WORK SUMMARY, ECOs EVALUATED
ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS, Fort SILL, OKLAHOMA

ECO DESCRIPTION IN SOW	SOW LOCATION	ECO NO.	ECO DESCRIPTION IN REPORT
Controls to assure proper combustion air-fuel ratio.	Annex A	10	Installation of combustion controls.
Installation of new burner equipment.	Annex A	11	Installation of new high efficiency burner.
Economizer or air preheater.	Annex A	12	Installation of stack economizer or air preheater.
Loading characteristics and scheduling versus equipment capacity (equipment optimization).	Annex A	2 & 8	2 - Chiller optimization. 8 - Boiler optimization.
Control systems to operate chillers at the most energy efficient operating condition.	Annex A	2	Chiller optimization.
Variable or two-speed cooling tower fan.	Annex A	5(A) & 5(B)	5(A) Two-speed motors. 5(B) Variable speed control.
Storage of chilled water or other thermal storage systems.	Annex A & Conf. Notice 1	4	Ice storage cooling system.
High efficiency motors.	Annex A	6	High efficiency motors.
Instruments and controls to facilitate efficient operations.	Annex A	1 & 7	1 - Chiller instruments. 7 - Boiler instruments.
Use smaller boilers where load has been reduced.	Annex A	8	Boiler optimization.
Replace inefficient boilers with more efficient boilers (or repair).	Annex A (para 7.2.1)	9	Renovate or replace boilers.
Replace inefficient chillers with more efficient chillers (or repair).	Annex A (para 7.2.1)	3	Renovate or replace chillers.

Appendix A

GENERAL SCOPE OF WORK

FOR AN

ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS

FOR

FORT SILL, OKLAHOMA

Performed as part of the

ENERGY ENGINEERING ANALYSIS PROGRAM

Exhibit 1

1. BRIEF DESCRIPTION OF WORK: The Architect-Engineer (AE) shall:

1.1 Determine the efficiency of the boiler/chiller plants by appropriate tests.

1.2 Survey the boiler/chiller plants to determine if efficiency can be improved by the repair, addition, or modification of equipment, control systems and operation and maintenance practices and recommend improvements.

1.3 Identify all energy conservation opportunities (ECOs) including low cost/no cost items and perform complete evaluations of each.

1.4 (Deleted)

1.5 (Deleted)

1.6 Prepare a comprehensive report to document the work performed, the results and recommendations.

2. GENERAL

2.1 Other studies performed under the Energy Engineering Analysis Program (EEAP) have been performed at the installation and may have included the boiler/chiller plants. Results of the previous studies concerning the boiler/chiller plants shall be included in this study. Boiler/chiller plant projects recommended in the previous studies shall be updated and included in this report if they have not been implemented or programmed. Any reports or studies that may have been accomplished on the boiler/chiller plants shall be reviewed by the AE and information included in this report as applicable.

2.2 The information and analysis outlined herein are considered to be minimum essentials for adequate performance of this study.

2.3 This study shall include the boiler plant, chiller plant, all appurtenances, and supporting systems (e.g., fuel storage facilities, pollution abatement, water treatment, etc.). It does not include steam or chilled water distribution systems. However, if during the survey readily identifiable energy conservation opportunities pertaining to the distribution systems are noted, they shall be listed in the report.

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2.4 The "Energy Conservation Investment Program (ECIP) Guidance," described in letter from CEHSC-FU, dated 25 April 1988, and revised in letter from CEHSC-FU-P, dated 15 June 1989, establishes criteria for ECIP projects and shall be used for performing the economic analysis of all projects or improvements considered.

2.5 Energy conservation opportunities determined to be technically and economically feasible shall be developed into projects acceptable to installation personnel. This may involve combining similar ECOs into larger packages which will qualify for ECIP or MCA funding, and determining, in coordination with installation personnel, the appropriate packaging and implementation approach for all feasible ECOs. Energy conservation opportunities which do not fit into projects, such as operation procedure changes, shall be developed into detailed and specific instructions and procedures for operating personnel.

2.6 Projects which qualify for ECIP funding shall be identified, separately listed, and prioritized by the Savings to Investment Ratio (SIR).

2.7 All feasible non-ECIP projects shall be ranked in order of highest to lowest SIR.

2.8 Energy Conservation and Management (ECAM) projects for procurement-funded installations will be identified and analyzed using the same criteria as for ECIP. ECAM and ECIP will be considered synonymous in this Scope of Work.

3. PROJECT MANAGEMENT

3.1 Project Managers. The AE shall designate a project manager to serve as a point of contact and liaison for all work required under this contract. Upon the award of the contract, this individual shall be immediately designated in writing. The AE's designated project manager must be approved by the Contracting Officer prior to commencement of work. This designated individual shall be responsible for complete coordination of work required under this contract. The Contracting Officer will designate a project manager to serve as the Government's point of contact and liaison for all work required under this contract. This individual will be the Government's representative.

3.2 Installation Assistance. A coordinator designated by the Commanding Officer at each installation will serve as the point of contact for obtaining available information and assist-

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ing in establishing contacts with the proper individuals and organizations as necessary to accomplish the work required under this contract.

3.3 Public Disclosures. The AE shall make no public announcements or disclosures relative to information contained or developed under this contract, except as authorized by the Contracting Officer.

3.4 Meetings. Meetings will be scheduled whenever requested by the AE or the Contracting Officer for the resolution of questions or problems encountered in the performance of the work. The AE and/or the designated representative(s) shall be required to attend and participate in all meetings pertinent to the work required under this contract as directed by the Contracting Officer. These meetings, if necessary, are in addition to the presentation and review conferences.

3.5 Site Visits, Inspections, and Investigations. The AE, consultants, if applicable, and/or designated representative(s) thereof shall visit and inspect/investigate the site of the project as necessary and required during the preparation and accomplishment of the work.

3.6 Records

3.6.1 The AE shall provide a record of all significant conferences, meetings, discussions, verbal directions, telephone conversations, etc., with Government representative(s) relative to this contract in which the AE and/or designated representative(s) thereof participated. These records shall be dated and shall identify the contract number, and modification number, if applicable, participating personnel, subject discussed and conclusions reached. The AE shall forward to the Contracting Officer within ten calendar days, a reproducible copy of the records.

3.6.2 The AE shall provide a record of requests for and/or receipt of Government-furnished material, supplies, data, documents, information, etc., which if not furnished in a timely manner, would significantly impair the normal progression of work under this contract. The record shall be dated and shall identify the contract number and modification number, if applicable. The AE shall forward to the Contracting Officer within ten calendar days, a reproducible copy of the record of request or receipt of material.

3.7 Interviews. The AE and the Government's representative shall conduct entry an exit interviews with the Director of Engineering and Housing before starting work at the facility and after completion of the field work. The Government's representative shall schedule the interviews at least one week in advance.

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3.7.1 Entry. The entry interview shall thoroughly brief and describe the intended procedures for the survey and shall be conducted prior to commencing work at the facility. As a minimum, the interview shall cover the following points:

a. Schedules.

b. Names of energy analysts who will be conducting the survey.

c. Proposed working hours.

d. Support requirements from the Director of Engineering and Housing.

3.7.2 Exit. The exit interview shall include a thorough briefing describing the items surveyed and probable areas of energy conservation. The interview shall also solicit input and advice from the Director of Engineering and Housing.

4. <u>SERVICES AND MATERIALS</u>. All services, supplies, materials (except those specifically enumerated to be furnished by the Government), plant, labor, testing equipment, superintendence and travel necessary to perform the work and render the data required under this contract shall be included in the lump sum price of the contract.

5. <u>PROJECT DOCUMENTATION</u>. All energy conservation opportunities which the AE has considered shall be included in one of the following categories and presented as such in the report:

5.1 <u>ECIP Projects</u>. To qualify as an ECIP project, an ECO, or several ECOs which have been combined, must have a construction cost estimate greater than $200,000, a Savings to Investment Ratio greater than one and a simple payback period of less than eight years. For ECAM projects the $200,000 limitation may not apply. The AE shall check with the installation for guidance. The overall project and each discrete part of the project shall have a SIR greater than one.

A Life Cycle Cost Analysis Summary Sheet shall be developed for each ECO and for the overall project when more than one ECO is combined. For projects and ECOs updated or developed from the previous studies, the backup data shall consist of copies of the original calculations and analysis, with new pages revising the original calculations and analysis. In addition, the backup data shall include as much of the following as is available: the increment of work the project or ECO was

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developed unuer in the previous study, title(s) of the project(s), the energy to cost (E/C) ratio, the benefit to cost (B/C) ratio, the current working estimate (CWE), and the payback period. This information shall be included as part of the backup data. The purpose of this information is to provide a means to prevent duplication of projects in any future reports.

5.2 Non-ECIP Projects. Projects which normally do not meet ECIP criteria, but which have an overall SIR greater than one shall be individually packaged and fully documented. The Life Cycle Cost Analysis Summary Sheet shall be completed through and including line 6 for all projects or ECOs. Each shall be analyzed to determine if they are feasible even if they do not meet ECIP criteria. These ECOs or projects may not meet the nonenergy qualification test. For projects or ECOs which meet this criteria, the Life Cycle Cost Analysis Summary Sheet, completely filled out, with all the necessary backup data to verify the numbers presented, a complete description of the project and the simple payback period shall be included in the report.

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5.3 Nonfeasible ECOs. All ECOs which the AE has considered but which are not feasible, shall be documented in the report with the reasons and justifications showing why they were rejected.

6. DETAILED SCOPE OF WORK: The general Scope of Work is intended to apply to contract efforts for all Army boiler and chiller plants except as modified by the detailed Scope of Work for each specific installation. The detailed Scope of Work is contained in Annex B.

7. WORK TO BE ACCOMPLISHED

7.1 Determine Efficiency

7.1.1 Boilers. The efficiency of the existing boiler installation shall be determined by field testing. The AE shall provide equipment and perform tests in the field to establish the efficiency of the boilers. The tests are intended to determine the efficiency of the boilers as they are actually being operated. The AE shall document any changes made to controls or equipment during boiler efficiency tests.

The AE shall submit the proposed test procedure and testing laboratory to the Contracting Officer for approval. Based upon the results of the tests, any indicated areas of improvement or equipment modification shall be fully analyzed. The study shall establish equipment operating data baselines, system efficiency modeling, and evaluate plant and unit loading profiles versus equipment capacities. The Government will furnish fuel, utilities, other consumables, and provide personnel to operate the plant during testing. All test and/or measurement equipment shall be properly calibrated prior to its use.

7.1.2 Chillers. The efficiency of the existing chiller plant shall be analyzed and evaluated to determine if system efficiency can be improved or energy saving improvements implemented. The efficiency of the existing chillers shall be calculated using standard methods. Meters shall be used to obtain the necessary data to calculate efficiency. The AE is responsible for any metering necessary. If meters are existing, they may be used if their validated accuracy is within the limits specified below. If no meters are present, the AE is responsible for installing temporary meters. Permanent taps or connectors shall be installed so as to cause minimal disruptions to the system. Ultrasonic metering may be used. All meters used must have an accuracy of ± 2 percent and a statement to that effect, signed by an independent testing laboratory must be included in the report. Efficiency tests shall be made at normal operating parameters.

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7.2 Survey Existing Plants

7.2.1 The condition of the existing plant shall be studied, documented, and evaluated. possibilities of repairing or replacing equipment or revising systems which will result in improved efficiency or reduced cost of operation shall be investigated.

7.2.2 The existing control system will be investigated, evaluated and documented to determine if equipment can be improved through upgrading, adjustment, repair or replacement, and if an alternate control system would increase efficiency. If an alternate system is recommended, interim improvements to existing controls shall also be recommended, if applicable. Engineering and economic analysis shall be developed. New controls proposed shall be Energy Monitoring and Control Systems (EMCS) compatible. Corps of Engineers Guide Specification (CEGS) 13946, Building Preparation for EMCS, shall be used as a standard for an interface to the existing plant. If an EMCS exists, interaction between this system and proposed modifications shall be clearly defined. The AE shall notify the DEH at least ten days prior to any pending outages of equipment and obtain concurrence prior to proceeding with any work.

7.2.3 The present boiler and chiller operation and maintenance practices shall be reviewed, documented, and evaluated with the intent to increase efficiency. The alternatives and recommendations shall be developed, evaluated, and documented in the report. Recommendations shall be in sufficient detail so that they can be quickly implemented. Detailed engineering and economic analysis of these actions are not required, however, a description and evaluation of these recommendations will be included in the report.

7.3 Identify ECOs. All methods of energy conservation which are reasonable and practical shall be considered, including operational methods and procedures and maintenance practices as well as physical facilities. A list of energy conservation opportunities is included as Annex A to this scope. This list is not intended to be restrictive but only to assure that at least these opportunities are considered, discussed and documented in the report. Each of the items shall considered and discussed in the report. Those items on the list which are not practical, have been previously accomplished, are inappropriate or can be eliminated from detailed analysis based on preliminary analysis shall be listed in the report along with the reason for elimination from further analysis. All potential ECOs which are not eliminated by preliminary considerations shall be thoroughly documented and evaluated as to the technical and economic feasibility. The AE shall provide all data and calculations needed to support the recommended ECO. All assumptions shall be clearly stated. Calculations shall be prepared showing how all numbers in the ECO were figured. Calculations shall be an or-

derly step-by-step progression from the first assumption to the final number. Descriptions of the products, manufacturers catalog cuts, pertinent drawings and sketches shall also be included. A Life Cycle Cost Analysis Summary Sheet shall be prepared for each ECO and included as part of the supporting data.

7.4 (Deleted)

7.5 (Deleted)

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7.6 Submittals, Presentations and Reviews. The work accomplished shall be fully documented by a comprehensive report. The report shall have a table of contents and be indexed. Tabs and dividers shall clearly and distinctly divide sections, subsections, and appendices. All pages shall be numbered. The AE shall give a formal presentation of all but the final submittal to installation, command, and other Government personnel. The AE shall prepare slides or view grapns showing the results of the study to date for his presentation. During the presentation, the personnel in attendance shall be given ample opportunity to ask questions and discuss any changes deemed necessary to the study. A review conference will be conducted the same day, following the presentation. Each comment presented at the review conference will be discussed and resolved or action items assigned. The AE shall provide the comments from all reviewers and written

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notification of the action taken on each comment to all reviewing agencies within three weeks after the review meeting. It is anticipated that each presentation and review conference will require approximately one working day. The presentation and review conferences will be at the installation on the date(s) agreeable to the Director of Engineering and Housing, the AE and the Government's representative. The Contracting Officer may require a resubmittal of any document(s), if such document(s) are not approved because they are determined by the Contracting Officer to be inadequate for the intended purpose.

7.6.1 Interim Submittal. An interim report shall be submitted for review after completion of the field survey and an analysis has been performed on all of the ECOs. The report shall indicate the work which has been accomplished to date, illustrate the methods and justifications of the approaches taken and contain a plan of the work remaining to complete the study. Calculations showing energy and dollar savings and SIRs of all the ECOs shall be included. The simple payback period of all ECOs shall be calculated and shown in the report. The AE shall submit the Scope of Work and any modifications to the Scope of Work as an appendix to the report. A narrative summary describing the work and results to date shall be a part of this submittal. During the review period, the Government's representative shall coordinate with the Director of Engineering and Housing and provide the AE with direction for packaging or combining ECOs for programming purposes and also indicate the fiscal year for which the programming or implementation documentation shall be prepared.

The survey forms completed during this audit shall be submitted with this report. The survey forms only may be submitted in final form with this submittal. They should be clearly marked at the time of submission that they are to be retained. They shall be bound in a standard three-ring binder which will allow repeated disassembly and reassembly of the material contained within.

7.6.2 Prefinal Submittal. The AE shall prepare and submit the prefinal report when all work under this contract is complete. The AE shall submit the Scope of Work for the installation studied and any modifications to the Scope of Work as an appendix to the submittal. The report shall contain a narrative summary of conclusions and recommendations, together with all raw and supporting data, methods used, and sources of information. The report shall integrate all aspects of the study. The report shall include an order of priority by SIR in which the recommended ECOs should be accomplished. The synergistic effects of all of the ECOs on one another shall have been determined and the results of the original calculations adjusted accordingly.

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The prefinal report, separately bound Executive Summary and all appendices shall be bound in standard three-ring binders which will allow repeated disassembly and reassembly. The prefinal submittal shall be arranged to include (a) a separately bound Executive Summary to give a brief overview of what was accomplished and the results of this study using graphs, tables and charts as much as possible (See Annex D for minimum requirements), (b) the narrative report containing a copy of the Executive Summary at the beginning of the volume and describing in detail what was accomplished and the results of this study, (c) appendices to include the detailed calculations and all backup material.

A list of all projects and ECOs developed during this study shall be included in the Executive Summary and shall include the following data from the Life Cycle Cost Analysis Summary Sheet: the cost (construction plus SIOH), the annual energy savings (type and amount), the annual dollar savings, the SIR, the simple payback period and the analysis date.

7.6.3 Final Submittal. Any revisions or corrections resulting from comments made during the review of the prefinal report or during the presentation and review conference shall be incorporated into the final report. These revisions or corrections may be in the form of replacement pages, which may be inserted in the prefinal report, or complete new volumes. Pen and ink changes or errata sheets will not be acceptable. If replacement pages are to be issued, it shall be clearly stated with the prefinal submittal that the submitted documents will be changed only to comply with the comments made during the prefinal conference and that the volumes issued at the time of the prefinal submittal should be retained. Failure to do so will require resubmission of complete volumes. If new volumes are submitted, they shall be in standard three-ring binders and shall contain all the information presented in the prefinal report with any necessary changes made. Detailed instructions of what to do with the replacement pages should be securely attached to the replacement pages.

8. <u>OPERATION AND MAINTENANCE</u>. The contractor will identify operational items noted during the study, which will effect energy conservation, and will explain the savings possible.

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ANNEX A

GENERAL ENERGY CONSERVATION OPPORTUNITIES AND OTHER CONSIDERATIONS

General Energy Conservation Opportunities:

- o Controls to assure proper combustion air-fuel ratio.
- o Installation of new burner equipment.
- o Economizers/air preheaters.
- o Loading characteristics and scheduling versus equipment capacity (equipment optimization).
- o Control systems to operate chillers at their most energy efficient operating condition.
- o Variable or two-speed cooling tower fan.
- o Storage of chilled water.
- o High efficiency motors.
- o Instruments and controls to facilitate efficient operations.
- o Use smaller boilers where load has been reduced.
- o Replace inefficient boilers with more efficient boilers.
- o Replace inefficient chillers with more efficient chillers.

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o Generate electricity on-site with natural gas turbine engines and reclaim heat from those engines to produce steam for steam turbine chillers or domestic hot water/steam.

o Use natural gas engine driven chillers and reclaim heat from engines and condensers to produce domestic hot water.

Other Considerations (General Overview Only):

o Provide the general impact on efficiency and capacity of changing the refrigerant to an environmentally safe refrigerant.

o Generally, determine the extent of equipment modifications ("O" rings, gaskets, motor stators, controls, etc.) required for a new refrigerant.

o Generally, determine special life safety features required when new refrigerants are used (sensors, alarms, ventilation, etc.).

ANNEX B

DETAILED SCOPE OF WORK

1. General. This Detailed Scope of Work supplements the General Scope of Work and provides information and requirements specific to the Energy Survey of Army Boiler and Chiller Plants at Fort Sill. Any conflicts in requirements between the General and Detailed Scopes of Work will be resolved by the Corps of Engineers Project Manager.

2. Boiler/Chiller Plants to be Surveyed. Attachment 1 (Boiler/Chiller Plant List) to this Annex B lists the boiler/chiller plants (in priority order) to be surveyed under this contract. The Architect-Engineer (AE) will verify the pertinent data in Attachment 1 and develop a testing plan for each boiler/chiller. Those plans will outline the details of any modifications/attachments to plant equipment required in the tests and the plans will be provided to Fort Sill DEH for review and approval. The AE will comply with Occupational Safety and Health Administration (OSHA) Asbestos Standards 1910.1001 and 1926.58 and 40 CFR 61(m) in conducting any work involving asbestos. The AE will also address the Special Considerations outlined in Attachment 1 and present the findings in the report.

3. Previous Boiler/Chiller Plant Studies. As outlined in the General Scope of Work, the AE shall update boiler/chiller projects recommended in previous studies if they have not been implemented or programmed. The statuses of those previously recommended projects are as follows:

a. Central Energy Plant Nos. 445, 462, 730, 913, 1603, and 1653 to be replaced by single 800 Area central energy plant -- neither implemented nor programmed.

b. Chilled Water Plant No. 2471 (serving barracks Nos. 2470 and 2471) to be replaced with extension of chilled water piping from Plant No. 3442 -- designed, but not funded.

c. Central Energy Plant Nos. 5900 and 6003 to be expanded to serve future facilities -- Plant No. 5900 expansion has been completed; however, further expansion using waste oil/sludge fired boilers has been considered -- Plant No. 6003 expansion has neither been implemented nor programmed.

4. Government Furnished Information. The following information will be furnished as required and upon request of the AE:

a. Previously completed studies performed under the Energy Engineering Analysis Program (EEAP) and other programs. The AE may review study availability at Fort Sill DEH Energy Office.

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b. Fort Sill Energy Resources Management Plan.

c. ETL 1110-3-282, Energy Conservation.

d. ETL 1110-3-301, Entrance Doors to Heater/Boiler Rooms.

e. ETL 1110-3-318, Procedures for Programming Energy Monitoring and Control Systems (EMCS) Funded Through the MCA Program.

f. ETL 1110-3-332, Economic Studies.

g. ETL 1110-3-354, Direct Digital Control of Heating, Ventilation and Air Conditioning (HVAC) Systems.

h. Office, Chief of Engineers Architectural and Engineering Instructions, July 1989.

i. Energy Conservation Investment Program (ECIP) Guidance, dated 25 April 1988 and revision dated 15 June 1989.

j. Information on Existing EMCS Studies, Designs, Construction Contracts, or Operating Systems.

k. TM 5-785, Engineering Weather Data.

l. TM 5-800-2, General Criteria Preparation of Cost Estimates.

m. TM 5-800-3, Project Development Brochure.

n. TM 5-815-2, Energy Monitoring and Control Systems (EMCS).

o. AR 415-15, Military Construction Army (MCA) Program Development.

p. AR 415-17, Cost Estimating for Military Programming.

q. AR 415-20, Construction, Project Development and Design Approval.

r. AR 415-28, Department of the Army Facility Classes and Construction Categories.

s. AR 415-35, Construction, Minor Construction.

t. AR 420-10, General Provisions, Organization, Functions, and Personnel.

u. AR 11-27, Army Energy Program.

v. AR 5-4, Change No. 1, Depart of the Army Productivity Improvement Program.

w. HNDSP-84-076-ED-ME, Preliminary Survey and Feasibility Study for Energy Monitoring and Control Systems.

x. NCEL CR 82.030, Standardized EMCS Energy Savings Calculations.

y. HNDSP88-207-ED-ME, HNDSP88-208-ED-ME, HNDSP88-209-ED-ME, and HNDSP88-210-ED-ME, EMCS Cost Estimating Guides.

z. Latest applicable Engineering Improvement Recommendation System (EIRS) Bulletin.

aa. Example of a correctly completed implementation document for a project.

bb. A computer program titled Life Cycle Costing in Design (LCCID) is available from the BLAST Support Office in Urbana, Illinois for a nominal fee to AE. This computer program can be used for performing the economic calculations for ECIP and non-ECIP ECOs. The AE is encouraged to obtain and use this computer program The BLAST Support Office can be contacted at 144 Mechanical Engineering Building, 1206 West Green Street, Urbana, Illinois 61801. The telephone number is (217) 333-3977.

5. Submittals. The AE will make Interim, Prefinal, and Final submittals of the work under this contract as outlined in the General Scope of Work. Attachment 2 (Submittal List) to this Annex B lists the receiving offices, addresses, and number of copies for each submittal. The AE will make submittals directly to the offices listed with a copy of the transmittal letter to the Tulsa District Project Manager.

6. Delivery Schedule. The schedule for completing work under this contract is somewhat dependent on when the peak cooling and peak heating periods occur at Fort Sill. The following target milestones are based on boiler tests being completed by 1 March 1991. Chiller tests will be conducted during the summer of 1990.

Item	Date
Award AE Contract	24 Aug 1990
Interim Submittal	1 May 1991
Interim Submittal Comments	31 May 1991
Prefinal Submittal	1 Aug 1991
Prefinal Submittal Comments	30 Aug 1991
Final Submittal	30 Sep 1991

7. Project Managers/Coordinators. The following persons will serve as points of contact and liaison for all work required under this contract:

AE: (As designated at time of contract award)

Tulsa District: Merle London
US Army Engineer District, Tulsa
ATTN: CESWT-EC-PF
PO Box 61
Tulsa, OK 74121-0061
Tele. No. (918) 581-7991
FAX (918) 581-7365

Fort Sill: Gary Basham
US Army Field Artillery Center and Fort Sill
ATTN: ATZR-EE
Fort Sill, OK 73503-7200
Tele. No. (405) 351-3517
FAX (405) 351-6923

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ANNEX B - ATTACHMENT 1

BOILER/CHILLER PLANT LIST

Item	Plant	No. Chillers*	Tons	No. Boilers*	MBTU
Base	5900	5 (F)	2000	6 (F)	65.20
Base	6003	3 (F)	1300	3 (F)	16.20
Base	730	3 (F)	1440	4 (F)	15.99
Opt 1	2812	1 (F)	372	3 (F)	6.03
Opt 2	4701	2 (F)	610+	3 (F)	-
Opt 3	5676	1 (P)	375	2 (P)	2.98
Opt 4	5678	1 (P)	190	2 (P)	3.95
Opt 5	3442	2 (P)	1200	No Boilers	-
Opt 6	914	1 (P)	400	4 (P)	-
Opt 7	1603	1 (P)	345	4 (M)	-
Opt 8	3040	1 (P)	350	2 (P)	-
Opt 9	500	1 (P)	110	1 (P)	-
Opt 10	1490	1 (P)	150	2 (P)	-

NOTE: Above data were extracted from existing records and contain errors/omissions. A-E and Government will jointly verify the data prior to contract negotiations.

* (F) = Full Test, as detailed in Pre-Negotiation minutes.
(P) = Partial Test, as detailed in Pre-Negotiation minutes.
(M) = Minimum Test, as detailed in Pre-Negotiation minutes.

ANNEX B - ATTACHMENT 1 (Cont.)

Special Considerations.

Plant No. 730: Determine if capacity of plant is sufficient to serve additional buildings.

Plants Nos. 5676 and 5678: Determine the feasibility of interconnecting these two plants.

Plant No. 3442: Explore opportunity for central heating plant. This proposition was investigated in previous studies.

Plant No. 914: Determine feasibility of using one boiler to serve four buildings (similar to single chiller in plant).

Plant No. 4701: Plant was designed for hospital use, but is to be now used for other purposes. Consider downgrading system to low pressure steam and use excess capacity elsewhere.

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ANNEX B - ATTACHMENT 2

SUBMITTAL LIST
FORT SILL BOILER/CHILLER SURVEY

Organization	Submittals
USAED, Tulsa ATTN: CESWT-EC-PF/London PO Box 61 Tulsa, OK 74121-0061	5 cys - all submittals
USAED, Southwestern ATTN: CESWD-ED-MM/Hasley 1114 Commerce Street Dallas, TX 75242-0216	1 cys - all submittals
Commander, USAFACAFS ATTN: ATZR-EE/Basham Bldg 1945 Fort Sill, OK 73503-7200	3 cys - all submittals
Commander, TRADOC ATTN: ATEN-FE/Capra Fort Monroe, VA 23651-5000	1 cys - all submittals
Commander, HQUSACE ATTN: CEMP-ET/Beranek 20 Massachusetts Ave NW Washington, DC 20314-1000	Executive Summaries only
HQDA ATTN: DALO-TSE/Maj Davies Pentagon Washington, DC 20310-0561	Executive Summaries only
USAED, Mobile ATTN: CESAM-EN-CC/Battaglia PO Box 2288 Mobile, AL 36628-0001	Final Submittal only

ANNEX C

REQUIRED DD FORM 1391 DATA

(Deleted)

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ANNEX D

EXECUTIVE SUMMARY GUIDELINE

1. Introduction.

2. Boiler Data. (Number, sizes, efficiency, etc.)

3. Present Energy Consumption.

   o Total Annual Energy Used.

   o Source Energy Consumption.

     Electricity - KWH, Dollars, BTU
     Fuel Oil - GALS, Dollars, BTU
     Natural Gas - THERMS, Dollars, BTU
     Propane - GALS, Dollars, BTU
     Other - QTY, Dollars, BTU

   o Energy Consumption by Systems.

4. Historical Energy Consumption.

5. Energy Conservation Analysis.

   o ECOs Investigated.

   o ECOs Recommended.

   o ECOs Rejected. (Provide economics or reasons)

   o ECIP Projects Developed. (Provide list)*

   o Non-ECIP Projects Developed. (Provide list)*

   o Operational or Policy Change Recommendations.

   * Include the following data from the Life Cycle Cost Analysis Summary Sheet: the cost (construction plus SIOH), the annual energy savings (type and amount), the annual dollar savings, the SIR, the simple payback period and the analysis date. For all programmed projects also include the year in which it is programmed and the programmed year cost.

6. Energy and Cost Savings.

   o Total Potential Energy and Cost Savings.

   o Percentage of Energy Conserved.

o Energy Use and Cost Before and After the Energy Conservation Opportunities are Implemented.

7. Energy Plan.

o Project Breakouts with Total Cost and SIR.

o Schedule of Energy Conservation Project Implementation.

E M C ENGINEERS, INC.
2750 S. Wadsworth Blvd., Suite C-200
Denver, Colorado 80227
303/988-2951

CONFIRMATION NOTICE

CONFIRMATION NOTICE NO. 1

DATE: 5 July 1990

PROJECT: Central Energy Plant Study
Ft. Sill, Oklahoma

NOTES PREPARED BY: Carl E. Lundstrom
E M C Engineers, Inc.

DATE OF CONFERENCE: 4 June 1990

PLACE OF CONFERENCE: DEH Office, Ft. Sill, Oklahoma

PURPOSE OF CONFERENCE: Conference to discuss questions related to the Central Plant Study.

ATTENDEES: Carl E. Lundstrom, E M C Engineers, Inc.
Merle London, Tulsa District, COE
Jerry Schmidt, Ft. Sill DEH

CONFERENCE NOTES:

The following is a summary of the items discussed, the comments made, and the decisions made during the Conference.

1. The "Scope Reduction" pages were discussed. Mr. Schmidt agreed the scope reductions seemed reasonable in order to get the project within the project budget.

2. Mr. Lundstrom and Mr. London went through the original scope of services and made corrections, deletions, and changes related to the "Scope Reduction" pages.

3. Mr. London said he would revise the scope and mail a new request for proposal.

4. Mr. Lundstrom said he would start preparing a revised proposal.

FOR

Carl E. Lundstrom

cc: Merle London
Jerry Schmidt
Gary Basham
Carl Lundstrom

SCOPE REDUCTION

The following proposed scope changes to the "Energy Survey of Army Boiler and Chiller Plant For Ft. Sill, Oklahoma" are listed for Tulsa District's information.

TESTING:

CHILLER:

- o Eliminate cooling tower testing.
- o Reduce chiller testing metering to the minimum required to calculate efficiency performance at full load: chiller kW input, chilled water flow, chilled water supply and return temperature, condenser water flow, and condenser water supply and return temperature. Flow readings would be taken with ultrasonic flow meters.
- o The chiller testing would only involve measurements at one chilled water and one condenser water setpoint; plus taking the single point pressure, temperature, and kW measurements as originally indicated.
- o Interview operators and report condition.
- o Run chiller through operating range to observe conditions.
- o Observe cooling tower temperature control system.

BOILERS:

- o The boiler testing would involve
  - Taking orsat test (flue gas analysis measurements) while boilers is operating at low fire and high fire.
  - Record gas flow to boiler through existing meters if available.
  - Record temperature, pressure, and flow data through existing meters if available.
  - Correlate part load and full load capacity with manufacturers data and orsat test.
  - Interview operators and report condition of equipment.
  - Obtain operator log data that is available.

MEETINGS:

- o Eliminate the O&M training, and related materials.

ANALYSIS:

- o Eliminate 6 of 11 boiler energy conservation opportunities (ECO's) identified. ECO's left include:
  - Replacement of boilers.
  - Control systems.
  - Installation of new burners.

- Economizer/Air Preheater.
- High efficiency motors.

o Eliminate 5 of 10 chiller ECO's identified. ECO's left include:
  - Replacement of chillers.
  - Control systems.
  - Variable and two speed motors
  - Storage of chilled water or other thermal storage systems.
  - High efficiency motors.

o Eliminate all cooling tower ECO's.
o Eliminate cooling tower computer modeling
o Eliminate analysis of impact on existing chillers due to changing the refrigerant to an environmentally safe refrigerant and related requirements.

REPORT DEVELOPMENT:

o Eliminate programming document preparation.
o Eliminate implementation document preparation.
o Eliminate O&M training manual development.

[c:\jobs\p10f.12\scope.wp]

CONFIRMATION NOTICE

CONFIRMATION NOTICE NO. 2

DATE: 26 September 1990

PROJECT: Energy Survey of Army Boiler and Chiller Plants
Ft. Sill, Oklahoma
Contract No. DACA 56-90-C-0087

NOTICE
PREPARED BY: Carl E. Lundstrom
E M C Engineers, Inc.

This is to confirm a conversation on 11 September 1990 between Merle London, Project Manager, Tulsa District Corps of Engineers, and Carl E. Lundstrom regarding documents related to the contract.

Mr. Lundstrom discussed with Mr. London that four sets of information were prepared and circulated during the negotiations of the referenced contract, which more clearly defined and refined the scope of services. Mr. Lundstrom wanted to reconfirm that these four documents are made part of the contract by this confirmation notice. The three documents are:

- Confirmation Notice No. 1, dated 5 July 1990, regarding "Scope Reductions."
- Conference Notes, dated 1 May 1990.
- Basis of Fee, submitted with fee proposal.
- Test Procedures, dated 14 June 1990.

Mr. London agreed the documents are part of the contract.

C. E. Lundstrom

Carl E. Lundstrom, P.E.

CONFIRMATION NOTICE

Confirmation No. 3 EMC #3002.000

DATE: February 27, 1991

PROJECT: Energy Survey of Army Boiler and Chiller Plants
CONTRACT NO: DACA 56-90-C-0087

NOTICE PREPARED BY: Pawn Chulavatr
E M C Engineers, Inc.

DATE OF CONFERENCE: February 13, 1991

PLACE OF CONFERENCE: Ft. Sill, Oklahoma

SUBJECT: Exit Interview Meeting Notes

ATTENDEES:

Merle London	Tulsa District COE	(918) 581-7991
Serge Saltiel	DEH-Ft. Sill	(405) 351-5708
Jerry Schmidt	DEH - Engineer Design	(405) 351-4250
Carl Swenson	EMC Engineers, Inc.	(303) 988-2951
Pawn Chulavatr	EMC Engineers, Inc.	(404) 952-3697

The following is a summary of items discussed, the comments made, and the decision made during the meeting.

EMC reported the preliminary results of the boiler survey. EMC stated that the combustion efficiency test of boilers went well and only one boiler is out of commission (building 4701). There were a few other minor problems encountered. Overall the test results were satisfactory. The preliminary result of the boiler testing is averaging around 77% efficiency.

Mr. Swenson suggests Ft. Sill train specialized groups of personnel in testing/calibrating boilers in all central plants. He expresses the lack of permanent instrumentation such as stack temperature gauge, pump pressure gauge, and opening for flue gas testing on boilers in the central plant. Mr. London asked that these suggestions be put in the report. EMC agreed to incorporate findings and suggestions into the report.

EMC described present operating procedures of boilers in the central plants according to the boiler operators. EMC reported that the only boiler log data was obtained from Central Plant 5900. The other central plants do not have log data.

Mr. Schmidt expressed interest in creating a central heating plant as an addition to chiller central plant in buildings 3442 and 730, utilizing existing underground piping.

Special Notes:

1. For the purpose of determining the base load on central plants, EMC is using the assumption that the proposed buildings listed for the EMCS in the DD1391 Validation Study will be connected to the EMCS. These buildings will incorporate day/night setback and other energy savings associated with EMCS.

2. EMC found the heating and cooling log data was either known to be false (stated by the operators) or upon checking, has been determined to be invalid. Because of the lack of this information, EMC will estimate the loads on the central plants based on BTU per square feet data obtained from previous studies. EMC will also use sound engineering judgment in applying the historical load data to the building and plants involved in this study.

If this method is unsatisfactory, EMC must be notified as soon as possible.

Pawn Chulavatr

Pawn Chulavatr

CONFERENCE NOTES

DATE: 26 September 1990

PROJECT: Energy Survey of Army Boiler and Chiller Plants
Ft. Sill, Oklahoma
Contract No. DACA 56-90-C-0087

NOTICE
PREPARED BY: Carl E. Lundstrom
E M C Engineers, Inc.

DATE OF
CONFERENCE: 11 September 1990

PLACE OF CONFERENCE: DEH Conference Room, Ft. Sill, Oklahoma

PURPOSE OF CONFERENCE: Entry Interview

ATTENDEES: Merle London, Tulsa District, Corps of Engineers, (918) 581-7991
Carl Lundstrom, E M C Engineers, Inc., (404)952-3697
Carl Swenson, E M C Engineers, Inc., (303) 988-2951
Kenneth Rodgers, DEH HVAC, Ft. Sill
Jerry Schmidt, DEH, Ft. Sill, (405) 351-4250
Doug Cook, DEH Energy, Ft. Sill, (405) 351-3225

1. Mr. Lundstrom provided an overview of the scope of services, including testing, energy conservation opportunities (ECOs), and documentation of the plants to be evaluated.

2. Mr. Lundstrom described the test procedures to be conducted on the chillers and boilers. He described that the test on the chillers would be conducted immediately and the boiler testing would be conducted during winter months (December-February).

3. Mr. Lundstrom presented his list of personnel conducting the survey, his proposed schedule, and proposed working hours. Mr. Rodgers saw no problem providing RVAC shop personnel for the proposed survey schedule.

4. Mr. London discussed that EMC should be very careful when removing insulation, so as to not have asbestos problems. Mr. Lundstrom agreed with the situation. Mr. Schmidt agreed to contact Mr. Goode at Ft. Sill environmental regarding the testing of insulation for asbestos.

5. Mr. Lundstrom asked if it would be a problem to shut off chillers, or take load off of chillers temporarily so as to increase the load for testing purposes. Mr. Rodgers did not see a problem with this.

6. Mr. Swenson asked about the general condition of chillers and annual maintenance procedures. Mr. Rodgers explained the chillers are generally in good condition and the condensers are all cleaned before each cooling season.

7. Mr. Schmidt emphasized he is interested in adding more buildings to central plants, especially in those facilities where there is extra cooling capacity.

8. Mr. Cook discussed the Energy Department is interested in developing energy conservation projects for future funding.

9. Mr. Lundstrom agreed to prepare conference notes, and the meeting was adjourned.

Carl E. Lundstrom, P.E.

Enclosure: Meeting Agenda

ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS
FT. SILL
CONTRACT DACA56-90-C-0087

ENTRY INTERVIEW

AGENDA

1. GENERAL OVERVIEW OF PROJECT
- Testing of boiler and chillers for efficiency of plant.
- Determine current operating procedures of plants.
- Identify energy conservation opportunities (ECO).
- Perform analysis to determine energy consumption of plants, and evaluate ECO's.
- Prepare comprehensive report documenting the findings of the survey and analysis.
- Central Plants,
  5900
  6003
  730
  2812
  5676
  5678
  3442
  914
  4701

2. INTENDED PROCEDURES
- Chiller Testing, September 1990
- Boiler Testing, January 1991
  (see attached test procedures)

3. SCHEDULE - CHILLER TESTING
Tuesday, 9/11, Building 2812
Wednesday, 9/12, Building 6003
Thursday, 9/13, Building 730
Friday, 9/14, Building 730 & 914
Saturday, 9/15, Building 5900
Monday, 9/17, Building 5900
Tuesday, 9/18, Building 3442
Wednesday, 9/19, Building 5676
Thursday, 9/20, Building 5678
Friday, 9/21, Building 4701
Saturday, 9/22, optional
Monday, 9/24, optional

4. PERSONNEL CONDUCTING SURVEY

Carl E. Lundstrom
Carl A. Swenson
Jim Watters

5. PROPOSED WORKING HOURS

07:30 to 18:00 hours, dates as shown

6. DEH SUPPORT

One RVAC shop chiller personnel, to bring chillers on and off line for testing. Also EMC will interview RVAC personnel to determine how plants are currently operated.

7. DISCUSSION

Any chillers plants not operational that can not be tested?
Other

TEST PROCEDURES

Energy Survey of Army Boiler and Chiller Plants
Ft. Sill, Oklahoma

Date: 14 June 1990
EMC Project No.: P10F.012

[illegible] TESTING [illegible]

Boiler Testing:

The boiler test procedure is designed to determine the efficiency of the boiler plants. The procedure is based on the American Society of Mechanical Engineers (ASME) Power Test Code 4.1 and will utilize instrumentation provided by EMC Engineers, Inc. It is noted that this procedure does not strictly adhere to ASME PTC 4.1; it is designed to provide the necessary data while controlling costs. The data obtained during the testing will be used to analyze boiler-related Energy Conservation Opportunities (ECO's). A single reading of the following will be measured:

- Flue gas temperature
- Ambient (combustion) air temperature
- Flue gas CO_2 content
- Flue gas O_2 content
- Outside air temperature
- Outside air relative humidity
- Fuel flow (using existing meters)
- KW input to primary hot water circulation pumps
- Differential pressure on representative primary hot water circulation pumps

Boiler readings will be taken while the boiler is under steady state firing conditions to the extent practical. The test procedure is as follows:

1) Install Flue gas thermometer and sampling tube in the stack through existing penetrations if possible. If not, a new penetration will be made using a handheld drill.

2) For non modulating burners, set burner control to hi-fire setting (if applicable). Adjust controls of other boilers so that the boiler being tested fires continuously.

3) For modulating burners, set burner control to manual, constant setting. Adjust controls of other boilers so that the conditions of the boiler being tested remain relatively steady.[1]

4) Observe the following operating conditions relative to manufacturer's recommendations:

   - steam/hot water pressure/temperature setpoints
   - boiler water level

- flame configuration
- combustion control
- make-up water control
- leaking safety and other valves
- signs of leaking boiler tubes
- general condition of boiler insulation

5) Record data.

6) Remove instrumentation, return control settings to original positions.

Chiller Testing:

This chiller test procedure is made with the intent of determining the efficiency of the chiller plants. The procedure is based on the Air-Conditioning and Refrigeration Institute (ARI) Standard for Centrifugal or Rotary Screw Water-Chilling Packages (ARI 550-88). The procedure will utilize instrumentation provided by EMC Engineers, Inc. It is noted that this procedure does not strictly adhere to ARI 550-88; it is designed to provide the necessary data while controlling costs. The data obtained during the testing will be used to analyze chiller-related ECO's. A single set of readings of the following points will be metered:

- Condenser water inlet temperature
- Condenser water outlet temperature
- Chilled water return temperature
- Chilled water supply temperature
- Chilled water flow
- Chiller Compressor KW input
- Outside air temperature
- Outside air relative humidity
- KW input to chilled and condenser water pumps
- Differential pressure on representative chilled and condenser water pumps
- Condenser inlet/outlet pressure differential
- Evaporator inlet/outlet pressure differential

Readings will be taken at normal chilled water and condenser water supply temperature setpoints. "Normal setpoints" is meant to mean the setpoints used under normal operating conditions by the Ft. Sill maintenance staff. The test procedure is as follows:

1) Install all chiller test equipment.

2) Adjust setpoints to normal positions. Allow time for chiller to reach steady-state

conditions. Steady-state is considered to be established after three sets of data have been taken, at five minute intervals, where the readings remain within the tolerences set forth in ARI 550-88, Para. A7.2.

Practical steps will be taken to obtain steady-state conditions. If these conditions are not reached within 1 hour, the EMC test engineer will use his discretion as to how to proceed with the testing.

3) Have DEH personnel remove all non-condensables from the system.

4) During the testing, observe the following operating conditions relative to manufacturer's recommendations:

- refrigerant charge
- temperatures and pressures
- speed control

5) After the chiller conditions have stabilized, take a single set of readings.

6) Remove instrumentation.

At the time of the tests, DEH personnel will be interviewed as to the time of last cleaning and the general cleanliness of all heat exchangers. This information will be used to estimate fouling factors.

BASIS OF FEE

Energy Survey of Army Boiler and Chiller Plants
Ft. Sill, Oklahoma

The proposal for the above project is based on the following items:

1. EMC will use existing natural gas meters in the boiler plants at Ft. Sill. EMC will not install any additional gas meters.

2. One complete set of metering equipment will be used. This equipment will all be direct readout type equipment; an electronic data acquisition system with sensors, PC, etc. will not be used. Equipment purchased for the project and to be given to the Government at the end of the project are as follows:

   - (2) Stack Thermometers
   - (1) Ultrasonic Flow Meter
   - (6) Thermometers
   - (1) Handheld Flue Gas Analyzer
   - (6) Pressure Gages

3. Asbestos Containing Materials (ACM) removal will amount to no more than (8) horizontal type 44" wide by 60" long glove bags.

4. Any material that is suspected by EMC to be ACM will be treated as ACM unless that material is sampled, tested, and positively identified by the Government as not being ACM. Sampling and testing must be performed according to all applicable EPA, OSHA, and other Federal, State, Regional, and Local regulations.

5. All ACM removal will be classified by EPA regulations as "O & M removal".

6. All ACM removed will be disposed of at the approved ACM disposal site at Ft. Sill.

7. All necessary pipe penetrations are existing. No additional pipe penetrations will be required for the testing.

8. Equipment outages of short duration will be required to connect meters. It is not expected that these outages will significantly effect plant operation. A general schedule of outages will be provided at the survey entrance interview. Given the nature of the survey work, providing a detailed schedule of outages is not possible.

9. In Appendix A, General Scope of Work, Para. 2.1, the phrase "updated and included" is taken to mean as follows: No technical analysis will be done under this contract. An

CONFERENCE NOTES

DATE: 1 May 1990

PROJECT: Ft. Sill
Energy Survey of Army Boiler and Chiller Plants

NOTES PREPARED BY: Carl E. Lundstrom, P.E.
E M C Engineers, Inc.

DATE OF CONFERENCE: 17 April 1990

PLACE OF CONFERENCE: DEH Office, Ft. Sill, Oklahoma

PURPOSE OF CONFERENCE: Pre-negotiation conference to discuss questions related to the Ft. Sill energy survey of Army boiler and chiller plants

ATTENDEES:
F. Mike Denham, E M C Engineers, Inc., (303)988-2951
Carl E. Lundstrom, E M C Engineers, Inc., (404)952-3697
Merle London, Tulsa District, COE, (918)581-7991
Gary W. Basham, Ft. Sill DEH, (405) 351-3517
Jerry E. Schmidt, Ft. Sill DEH, (405) 351-4250
Steve McManus, Ft. Sill Energy Conservation Office, (405) 351-3225
Ron Barnett, Environmental Division, (405) 351-2715
Don Goode, Environmental Division, (405) 351-2715

CONFERENCE NOTES:

The following is a summary of the items discussed, the comments made, and the decisions made during the Conference. The A/E statement of work and conference agenda were distributed to each person.

1. M. London opened the conference with general introductions and explanation of the scope of the project. EMC is to survey boilers and chillers at Ft. Sill, determine their operating efficiency, evaluate energy conservation opportunities, and prepare three submittals of the testing and analysis. In addition EMC is to provide a one-day training seminar.

2. Asbestos removal concerns were discussed with R. Barnett. EMC will be installing instrumentation on the boilers and chillers to test their efficiency. Piping and flue insulation will have to be removed. Unless the insulation has been sampled, tested and positively

identified as not having asbestos containing material (ACM), it will be treated as asbestos. Paragraph 2. in Annex B, in the statement of work, identifies the OSHA standard which must be followed by workers that will be in areas with ACM's. R. Barnett explained if ACM will be removed and disposed of, EMC must follow EPA regulation Title 40CFR 61 (m). It was felt the work would be classified as O&M removal. EMC should investigate inspection notification, ACM removal, and ACM disposal requirements. EMC will have to contract with a licensed ACM removal contractor for this work. The government has an approved ACM disposal site at Ft. Sill for the material.

The following questions relate to Appendix A, General Scope of Work for an Energy Survey of Army Boiler and Chiller Plants for Ft. Sill Oklahoma:

3. Paragraph 2.1: Only the previous studies identified in Annex 'B' paragraph 3.a.b.& c. and related projects in Annex 'B' attachment 1 (cont.) must be updated and included in this study.

4. Paragraph 2.3: The statement that the study shall include supporting systems such as fuel oil storage, pollution abatement, etc. is meant to only note those items related to the existing boiler and chiller plant, which seem not normal, in need of repair, etc. Detailed evaluation of these items is not required.

5. Paragraph 2.3: The study is not intended to include a detailed evaluation of the distribution systems related to the central plants. If EMC notes problems while on-site (such as steam leaks in piping pits) these items should be described briefly in the report.

6. Paragraph 2.5: The term "technically and economically feasible," is meant to be those items which have been done and proven to provide savings, i.e. nothing experimental. All ECO's should be coordinated with DEH on what's feasible for Ft. Sill.

7. Paragraph 2.8: ECAM evaluation does not apply to Ft. Sill. Delete this requirement from the statement of work.

8. Paragraph 3.4: EMC will not be required to attend any non-scheduled meetings. EMC will have a kickoff meeting at the beginning of the field survey, and an exit interview, plus the scheduled submittal review meetings.

9. Paragraph 3.7.1.c: There will be no major restrictions on the working hours for EMC. EMC shall coordinate it's working schedule with DEH.

10. Paragraph 7.1.1: The statement of work regarding "submit...testing laboratory to the Contracting Officer for approval, is meant to include submitting documentation showing testing equipment has been properly calibrated.

11. Paragraph 7.1.1: The efficiency testing requirements for boilers were divided into full testing, partial testing, and minimum testing requirements, based on the size and age of the plants (see Annex B - attachment 1).

Full efficiency testing is to include: Installation of instrumentation for input/output measurement required to meter energy in versus energy out. See attached diagrams for instrumentation of low temperature hot water boilers (LTHW), high temperature hot water boilers (HTHW), and steam boilers.

Partial efficiency testing is to include: Stack temperature and CO measurements to determine the boiler combustion efficiency, plus overall inspection of the general boiler condition and operation. See attached diagrams for instrumentation of low temperature hot water boilers (LTHW), high temperature hot water boilers (HTHW), and steam boilers.

Minimum testing is to include: Overall inspection of the general condition and operation. No instrumentation will be used for this testing.

It is assumed one set of instrumentation equipment will be used for the measurements. This set of instrumentation will be moved from boiler to boiler to make the required measurements. In those locations where an insertion flow meter will be used, a new pipe tap and full bore valve will be installed and left in place after the metering is complete.

EMC will be required to remove asbestos insulation on pipes and stacks as required to make measurements (see item 2.).

12. Paragraph 7.1.2: The efficiency testing requirements for chillers were divided into full testing, partial testing, and minimum testing requirements, based on the size and age of the plants (see Annex B - attachment 1).

Full efficiency testing is to include: Installation of instrumentation for input/output measurement required to meter energy in versus energy out. See attached diagrams for instrumentation of chillers.

Partial efficiency testing is to include: The same as full efficiency testing minus the flow metering installation. See attached diagrams for instrumentation of chillers.

Minimum testing is to include: Overall inspection of the general condition and operation. No instrumentation will be used for this testing.

It is assumed one set of instrumentation equipment will be used for the measurements. This set of instrumentation will be moved from

chiller to chiller to make the required measurements. In those locations where an insertion flow meter will be used, a new pipe tap and full bore valve will be installed and left in place after the metering is complete.

For the full and partial testing EMC will measure the efficiency of the plants at varying loads at the following setpoints:

- Chilled water supply setpoints: 44°, 46°, and 48°, at the normal condenser water setpoint temperature.
- Condenser water supply setpoints: 87, 85, and 82, at the normal chilled water supply setpoint temperature.

EMC will be required to remove asbestos insulation on pipes as required to make measurements (see item 2.).

13. Paragraph 7.2.3: This paragraph is not intended to write an O&M manual for boiler and chiller operation. Include O&M items which would be covered in the one-day training class related to this project.

14. Paragraph 7.5: It was decided $25,000 or less was the limit for a low cost/no cost ECO.

15. Paragraph 7.6.1: The sample completed DA Form 5108-R should be submitted with the interim submittal. EMC should coordinate with DEH which project should be submitted prior to the interim submittal.

16. Paragraph 8.: EMC will be required to give the one-day training class on three consecutive days, to three different classes of maintenance personnel at Ft. Sill. EMC should estimate on having 15 persons per class.

General comments and questions:

17. Mr. Lundstrom asked about evaluating manpower operation requirements. Mr. Basham explained this was a touchy subject, but is an important area to review. EMC should coordinate all information very closely with DEH, prior to submittals.

18. Mr. Lundstrom explained that to perform detailed ECO calculations, detailed boiler log data would provide the best method of estimating hourly loads. Because there are little or no log data kept, EMC will have to estimate loads, from gross capacities, or what little monthly metering data that's available.

19. After the study is complete, EMC will leave the metering equipment for government to use. There is little or no measurement or metering instrumentation on the central plants. This equipment can be used in the future for metering and adjusting central plant equipment operations. Some of the metering equipment will be site specific for the metering installations.

20. EMC will have to review the scheduling impact of: 1) submitting metering plan for approval, and 2) having contractors install metering taps and asbestos abatement.

21. Annex A, regarding impact of new refrigerants, EMC will address: 1) the general question of the affect refrigerant changes will have on Ft. Sill, and the central plants in question, 2) generally what efficiency, equipment changes, capacity, and life expectancy changes will occur, 3) manufacturers input to equipment changes required, 4) a general discussion on cost to convert chillers versus replacement of chillers, 5) life safety requirements for new refrigerants, and 6) general design guidelines and directives for future chiller plant designs. Specific chiller by chiller evaluation for technical modifications will not be provided in this study.

Ft. Sill DEH is to provide EMC with copies of the as-built mechanical plans for the chiller and boiler plants that will require instrumentation installations for measurement, for EMC to prepare a construction estimate for their fee proposal. Ft. Sill is to provide EMC a list of names of mechanical and asbestos abatement contractors who have worked at Ft. Sill.

Tulsa District needs to provide the following documents for EMC to prepare their fee proposal:

1. AR415-17, Tri-Service MCP Index, and EIRS bulletin.
2. Latest ECIP guidance.
3. AR5-4, change no. 1.
4. ETL 1110-3-332.
5. AR415-15, MCP Data, DD Form 1391
6. AR415-20.
7. TM5-800-3 for PDB.
8. Copy of a completed PDB.
9. DA Form 5108-R, copy of a blank form, instructions for completing the form, and a completed form as an example.
10. Copy of a completed DA Form 5108-R.
11. Example completed implementation document

Carl E. Lundstrom, P.E.
Project Manager

[C:\JOBS\SILL\CONFNOTE.WP]

economic analysis will be done using the previous technical analysis results and current economic data. Construction cost estimates from the previous studies will be adjusted for inflation. All necessary technical analysis results from the previous studies will be provided by the Government. Only previous studies that effect the boiler/chiller plants in this study and that are identified in Annex B, Attachment 1, Detailed Scope of Work will be included in this study.

10. The manufacturer's published technical data will be sufficient certification of accuracy for meters and other test equipment that are new (not previously used).

11. EMC will have the full-time assistance of a boiler/chiller operator from Ft. Sill to perform equipment changeover. This will require approximately 1-1/2 weeks during the chiller testing in July or August 1990 and approximately 1 week during the boiler testing in January 1991.

12. Annex A to the General Scope of Work "General Energy Conservation Opportunities and Other Considerations" is revised to eliminate redundant ECO's and to combine certain ECO's to allow for practical implementation and valid technical analysis. Annex A will read as follows:

General Energy Conservation Opportunities:

1) Replacement of Boilers
2) Installation of New Burners and Control Systems (to assure proper combustion air-fuel ratio and most economical operation, including equipment optimization)
3) Economizers/Air Preheaters
4) High Efficiency Motors on Primary Hot Water Circulation Pumps and Chilled and Condenser Water Pumps.
5) Variable or Two Speed Motors on Primary Hot Water Circulation Pumps and Chilled and Condenser Water Pumps.
6) Replacement of Chillers
7) Control Systems (to operate chillers at most economical conditions, including equipment optimization)
8) Storage of Chilled Water

13. No additional ECO's will be analyzed in detail. No ECAM projects will be included. A general discussion of possible low cost / no cost ECO's observed during the surveys will be included in the report.

14. No heating or electrical load calculations are included. These loads will be provided by the Government, as required.

15. EMC project team members will make four trips to Ft. Sill. They are as follows:

    1) Chiller testing (approximately 1-1/2 weeks)
    2) Boiler testing (approximately 1 week)
    3) Interim Report Submittal Presentation
    4) Prefinal Report Submittal Presentation

16. No more than two EMC personnel will take part in each site visit to Ft. Sill. This includes the surveys and the submittal presentations.

17. Boiler/Chiller plants 5900, 6003, and 730 are included.

18. Travel costs were established based on 14 day prior notice.

Any additional effort to that indicated above will be accomplished through a modification to the contract.

8.15.91

FORT SILL REVIEW COMMENTS			DATE	ACTION
DIRECTORATE OF ENGINEERING & HOUSING			DISCIPLINE ☐ CIVIL ☐ ARCHITECTURAL ☐ MECHANICAL ☐ ELECTRICAL ☐ FIRE PROTECTION ☒ M P	A CONCUR D DO NOT CONCUR E EXCEPTION X DELETE (EXPLAIN D, E, & X)
PROJECT BOILER/CHILLER SURVEY				
LOCATION FORT SILL		PROJECT NUMBER		ACTION BY
CMT. NO.	DWG. NO. OR REF.	REVIEWER SERGE SALTIEL	PHONE NUMBER (405) 351-~~4250~~ 5708	COMPLY
		EXECUTIVE SUMMARY		
1.	ES 2	THIS ANALYSIS SHOULD BE INDEPENDENT OF THE EMCS. CAN NOT ASSUME THAT THE EMCS WILL BE INSTALLED	✓	
2	ES 3	THIS STUDY SHOULD VALIDATE IF A CENTRAL PLANT ADDITION TO 3442 IS A GOOD PROJECT	✓	
3	ES 3/4	OPERATIONAL NOTES TO SAVE ENERGY WITH LOW OR NO COST ARE TOO GENERAL.	✓	
4	ES 5	STATEMENT ABOUT THE 3442 PLANT ADD. (SAME AS COMM. 2) MUST BE VALIDATED TO SEE IF WE SHOULD INCLUDE IN THE BRKS PROJECT.	✓	
5	ES 8	ECO LIST SHOWS 17 ITEMS DESCRIPTIONS ARE NOT CLEAR EXAMPLE: #1 & 7. HOW IS ESTABLISHING CHILLER & BOILER LOAD GOING TO SAVE ENERGY?	✓	

L 836 Army—Fort Sill, Okla.

PAGE 1 OF ____

FS Form 910
(DEH) 1 Aug 87

FORT SILL REVIEW COMMENTS

DATE 17 JUL 91

DIRECTORATE OF ENGINEERING & HOUSING

DISCIPLINE
- ☐ CIVIL
- ☐ ARCHITECTURAL
- ☐ MECHANICAL
- ☐ ELECTRICAL
- ☐ FIRE PROTECTION
- ☒ MP

ACTION
- A CONCUR
- D DO NOT CONCUR
- E EXCEPTION
- X DELETE

(EXPLAIN D, E, & X)

ACTION BY COMPLY

PROJECT BOILER/CHILLER SURVEY

LOCATION FORT SILL

PROJECT NUMBER

REVIEWER SERGE SALTIEL

PHONE NUMBER (405) 351-4250

CMT. NO.	DWG. NO. OR REF.	COMMENT	ACTION	
6	ES10	ECO NO 8 FOR BLDG 730 SHOWS AN SIR OF 2.2 & A PAYBACK OF 8 YEARS, HOWEVER ON TABLE ES-7 (PAGE ES21) THE SAME ECO IS SHOWN AS NOT FEASIBLE	WILL CORRECT TABLE ES-4 PAGE ES-10 ✓	
7	ES18/19	NEGATIVE PAYBACK YEARS IS MEANINGLESS. Use "NA"	✓	
8		GENERAL COMMENT. THE EXECUTIVE SUMMARY MUST RELATE THE OVERALL FINDINGS OF THE SURVEY, HOWEVER IT MUST CONTAIN SPECIFIC DESCRIPTION OF EACH RECOMMENDATION FOR THE "EXECUTIVE" TO MAKE DECISIONS WITHOUT GOING TROUGH THE BACK-UP REPORTS. RECOMMENDATIONS ARE VERY GENERAL & PROPOSED SCOPE OF PROJECTS TOO HARD TO FOLLOW.	✓	

L 836 Army—Fort Sill, Okla.

FS Form 910
(DEH) 1 Aug 87

FORT SILL REVIEW COMMENTS	DATE 8 July, 1991	ACTION
DIRECTORATE OF ENGINEERING & HOUSING	DISCIPLINE	A CONCUR
ENERGY SURVEY OF ARMY BOILER & CHILLER PLANTS	CIVIL	D DO NOT CONCUR
	ARCHITECTURAL	E EXCEPTION
	XX MECHANICAL	X DELETE
LOCATION FORT SILL, OKLAHOMA · PROJECT NUMBER DACA 56-90-C-0087	ELECTRICAL	(EXPLAIN D, E & X)
	FIRE PROTECTION	
CMT. NO. · DWG. NO. · REVIEWER JERRY SCHMIDT	PHONE NUMBER (405)351-4250	ACTION BY COMPLY

VOLUME 1

CMT. NO.	DWG. NO.	COMMENT	ACTION
1.	2-19	Paragraph 2.2.4 The chillers in central plant building 3442 serves a total of 21 buildings.	✓
2.	2-34	Paragraph 2.2.8 and Paragraph 2.2.8.2 The central plant building 5900 serves a total of 5 barracks (bldgs. no. 5955, 5960, 5970, 6007 & 6050).	✓
3.	2-45	Central plant chiller should be 370 tons Table 2-2 shows chiller to be 170 tons.	✓
4.	2-46	Central plant (No. 5676) chiller should be 375 tons Table 2-2 shows chiller to be 170 tons.	VERIFY
5.	3-2	The distribution loss for the area served by the central plant in building have been more than negligible. The heat loss from the super heated hot water distribution system have caused sufficient ground heating to damaged some of the chilled water piping. If the ground heat was sufficient to cause damage to plastic piping systems then it stands to reason that the losses are more than negligible. Ground temp 155F w/ boilers on.	VERIFY FOR HTH. ✓ DISREGARD FOR CHW
6.	Tab 4	Annual savings for Ice Storage Systems was based on 12 months per year and the existing chiller efficiency. The use of Air Conditioning is only authorized 4 to 5 months per year and the existing chillers, modified to produce ice, will lose efficiency. The savings should be based on the actual period of use and the efficiency achieved while producing ice.	NA
7.	4-47	The estimated construction cost to replace the existing gas chiller appears to be excessive.	NA
8.	6-5	The chiller located at central plant 914 is a 400 ton chiller.	✓
9.	6-13	The central plant 6003 has three chillers one 400 ton and two 450 ton chillers. The operational strategies only addressed using the two 450 ton chillers.	✓

L 836 Army-Fort Sill, Okla.

FS Form 910
(DEH) 1 Aug 87

FORT SILL REVIEW COMMENTS	DATE 8 July, 1991	ACTION
DIRECTORATE OF ENGINEERING & HOUSING	DISCIPLINE CIVIL ARCHITECTURAL XX MECHANICAL ELECTRICAL FIRE PROTECTION	A CONCUR D DO NOT CONCUR E EXCEPTION X DELETE (EXPLAIN D, E & X)
ENERGY SURVEY OF ARMY BOILER & CHILLER PLANTS		
LOCATION FORT SILL, OKLAHOMA — PROJECT NUMBER DACA 56-90-C-0087		ACTION BY
CMT. NO. / DWG. NO. / REVIEWER JERRY SCHMIDT	PHONE NUMBER (405)351-4250	COMPLY

CMT. NO. / DWG. NO.	COMMENT	ACTION
10. 7-2	Brief description on ECO would be beneficial at this point.	✓
VOLUME II 11. C-3	Building 5900 chiller 4 should be listed as a 450 ton chiller.	✓
EXECUTIVE SUMMARY 12.	The executive summary should have included recommendation concerning the CFC issue. The base has a large number of chillers that would be affected by CFC legislation.	✓

L 836 Army-Fort Sill, Okla.

FS Form 910
(DEH) 1 Aug 87

CONFIRMATION NOTICE

Confirmation No. 4 EMC #3002.000

DATE: 19 August 1991

PROJECT: Energy Survey of Central Plants, Ft. Sill, Oklahoma
CONTRACT NO.: DACA56-90-C-0087

NOTES PREPARED BY: Carl Lundstrom
E M C Engineers, Inc.

DATE OF CONFERENCE: 15 August 1991

PLACE OF CONFERENCE: Tulsa District Resident Engineer's Office

SUBJECT: Interim Review Conference Presentation and Comments Review

ATTENDEES:
W. Wayne Kiser, DEH (405) 351-5708
Merle London, Tulsa District COE (918) 581-7991
Carl E. Lundstrom, EMC Engineers, Inc. (404) 952-3697
Gene Paulsgrove, DEH Master Planning (405) 351-5708
Kenneth Rogers, DEH (405) 351-5910
Serge Saltiel, DEH (405) 351-5708
Jerry Schmidt, DEH Engr. Design (405) 351-4250
Carl Swenson, EMC Engineers (303) 988-2951

The following is a summary of the items discussed, the comments made, and the decisions made during the Conference:

1. Mr. London made introductions and passed roster to attendees.

2. Mr. Lundstrom made a presentation of the Interim Submittal:

   - Survey Findings.
   - ECO Analysis.
   - Conclusions and Recommendations.

Based on the discussion of the presentation, the following items were concluded and project direction was determined:

- Review electrical rates to verify electric demand rate charges.

- ECO 3, Central Plant 914, repair chiller to increase efficiency: This ECO has been done under warranty service.

- ECO 4, Central Plant 914, ice storage: This ECO was rejected; savings are marginal.

- ECO 3, Central Plant 2812, replace chiller: This ECO was not economically justified as a replacement project. To repair the existing chiller is not an acceptable alternative.

- ECO 17, Central Plants 730 and 2812, electric water heaters: This ECO was rejected, because Ft. Sill does not want to do any projects which may increase the Fort's overall summer electrical demand.

- ECO 3, Central Plant 4701, replace chiller: This ECO was not economically justified as a replacement project. To repair the existing chillers is not an acceptable alternative.

- ECO 4, Central Plant 4701, ice storage: This ECO was rejected because of marginal savings.

- RDF boiler, Central Plant 5900: This special project to update a previous study was rejected because of current refuse quantities and operation of the plant.

- ECO 9, Central Plant 5900, replace boilers: This ECO will be investigated in place of the proposed repair project.

- ECO 12, Central Plant 5900, stack economizers: This ECO was rejected because or the potential increase in manpower to support operations.

- Central Plant 3442, service extension to provide cooling to Buildings 2470 and 2471: This special project is not required because these two buildings have new chiller equipment.

- ECO 6, high efficiency motors, all plants: In place of further analysis, it should be noted that high efficiency motors should be installed if replacements are justified.

- ECO 10, boiler combustion controls, all plants: No further analysis or consideration is required, because of the concern regarding the marginal savings and high maintenance requirements.

3. The Ft. Sill DEH engineers conferred as to proposed ECOs to develop into projects for the final submittal.

Based on their discussion, the following projects were developed:

Project A:
Boiler and chiller controls project (ECOs 1, 2, 7, and 8) for Central Plants 730, 914, 2812, 3442, 5676, 5678, 5900, and 6003. The control project is to be a stand-alone project, and the savings or costs should not assume an EMCS exists.

Project B:
Central heating plant replacement project at Central Plant 5900, boilers 1 and 2, and Central Plant 2812, boilers 1 and 2.

Project C:
One new central plant to provide heating and cooling to both Buildings 5676 and 5678.

In preparing the final analysis, Ft. Sill DEH engineers requested the energy analysis be based on the assumption the EMCS was not installed. Mr. Lundstrom agreed to use non-EMCS loads to prepare the final analysis. The Ft. Sill DEH engineers asked that the computer input for the final project energy analysis be included with the final report. Mr. Lundstrom agreed to provide this information.

4. Additional analysis comparison:

- Compare central heating plant at 3442, to individual boilers at each building. Consider plant to also serve Buildings 2470 and 2471. Do not consider using chilled water lines for distribution from heating plant.

Carl E. Lundstrom
/rt

If any portion of this Confirmation Notice is incorrect, please notify us immediately. If correspondence is not received to the contrary within 10 days, it will be assumed that the decisions and conclusions, and status outlined in this Confirmation Notice is correct.

CONFERENCE NOTICE

EMC #3002.000

Conformation No. 5

DATE: 10 September 1991

PROJECT: Energy Survey of Army Boiler and Chiller Plants Ft. Sill, Oklahoma
CONTRACT No. DACA 56-90-C-0087

NOTICE PREPARED BY: Kamchornvuthi Chulavatr
E M C Engineers, Inc.

DATE OF CONFERENCE: 6 September 1991

PLACE OF CONFERENCE: Public Work Center, Mr. Howard Hovis office, Ft. Sill, Oklahoma

SUBJECT: To discuss central plant's control strategy and projects to be evaluated in the study

ATTENDEES:
W. Wayne Keiser, DEH, Ft. Sill (405) 351-5708
Serge Saltiel, DEH, Ft. Sill (405) 351-5708
Jerry Schmidt, DEH, Ft. Sill, (405) 351-4250
Howard Hovis, PWC, Ft. Sill, (405) 351-3608/5341
Kamchornvuthi Chulavatr, E M C Engineers, Inc., (404) 952-3697

The following is a summary of the items discussed, the comments made, and the decisions made during the conference.

The control and monitoring points for central plants will include the following:

<u>Boiler</u>

- Natural gas line pressure before and after the regulator
- Flow and accumulative of the make-up water
- Boiler stack temperature and O_2
- Boilers alarm
- Pumps start/stop and status
- Supply and return water temperatures
- Flow of the supply steam and hot water
- Supply pressure for steam and nitrogen in the expansion tank for high temperature hot water
- LEDs display

<u>Chiller</u>
- Pumps start/stop and status
- Supply and return chilled water and condenser water temperatures
- Flow of the chilled water
- Chiller start/stop and status
- Cooling towers start/stop and status
- Chiller kW consumption
- LEDs display

Projects to be evaluated are:

- Project 1. - Control project for central plant 730, 5900, and 6003.
- Project 2. - Central plant project and control project for building 5676 and 5678.
- Project 3. - Replace boiler number 1 and 2 in central plant 2812 and 5900.
- Project 4. - Replace a chiller in central plant 2812 with the small higher efficiency chiller.
- Project 5. - Compare local hot water boiler in each barracks versus central heating plant project for 3442.

The following are result of general item discussed:

- The control project will include the fiber optics DTM cost from the central pant to RVAC shop, building 1950.
- There will not be any new control projects for central plant 914, 2812, and cooling plant 3442.
- The central computer for the control project will be an existing PC located in the RVAC shop, and, if possible, use existing software.

Kamchornvuthi Chulavatr

If any portion of this conformation notice is incorrect, please notify us immediately. If correspondence is not received to the contrary within 14 days, it will be assumed that the decisions and conclusions, and status outlined in this notice are correct.

CONFIRMATION NOTICE

EMC# 3002.000

Confirmation No. 6

DATE: 9 March 1992

PROJECT: Energy Survey of Army Boiler and Chiller Plants
Ft. Sill, Oklahoma

CONTRACT NO: DACA56-90-C-0087

NOTES PREPARED BY: Carl E. Lundstrom
EMC Engineers, Inc.

DATE OF CONFERENCE: 5 March 1992

PLACE OF CONFERENCE: Mr. Kiser's Office, Dept. of Public Works
Ft. Sill, OK

SUBJECT: To discuss results of the Prefinal report.

ATTENDEES: Carl Lundstrom, EMC Engineers, Inc. (404) 952-3697
Merle London, Tulsa District COE (918)-581-7991
Jerry Schmidt, Ft. Sill DPW, Engineering Design (405)-351-4250
Howard Hovis, Ft. Sill DPW, Chief FMD, (405) 351-3608
Gene Paulsgrove, Ft. Sill DPW, Planning, (405) 351-5708
W. Wayne Kiser, Ft. Sill DPW, Chief Engineering Division, (405) 351-5708

The following is a summary of the items discussed, the comments made, and the decisions made during the conference:

1. Mr. Lundstrom explained EMC finished and submitted the Prefinal report in October 1991.

2. Mr. Lundstrom reviewed the results of the evaluation of the five projects developed from the Interim Submittal.

3. Mr. Lundstrom went over the review comments made by Jerry Schmidt. Mr. Lundstrom confirmed he would make the following revisions to the final submittal:

   o Distribution losses for chilled water lines will be included in the project energy calculations for Central Plants 6003 and 5900.

- o Project 2: (Central Plants 5676 and 5678) will be reviewed as a heating plant replacement project only, with the idea of chiller plant replacement in the future.

- o Comments regarding Project 4 are not applicable, since the chiller is being replaced under a current construction project.

Carl E. Lundstrom, P.E.

If any portion of this confirmation notice is incorrect, please notify us immediately. If correspondence is not received to the contrary within 14 days, it will be assumed that the decisions and conclusions, and status outlined in this confirmation notice are correct.

SILL REVIEW COMMENTS

DATE: 6 November, 1991

ACTION:
A CONCUR
D DO NOT CONCUR
E EXCEPTION
X DELETE
(EXPLAIN D, E & X)

DIRECTORATE OF PUBLIC WORKS

ENERGY SURVEY OF ARMY BOILER & CHILLER PLANTS

DISCIPLINE:
CIVIL
ARCHITECTURAL
XX MECHANICAL
ELECTRICAL
FIRE PROTECTION

LOCATION: FORT SILL, OKLAHOMA

PROJECT NUMBER: DACA 56-90-C-0087

ACTION BY

CMT. NO.	DWG. NO.	REVIEWER: JERRY SCHMIDT	PHONE NUMBER: (405)351-4250	ACTION BY	
				-----	-----

VOLUME 1

1. 3-2 The distribution loss for the area served by the central plant in building 5900 and 6003 have been more than negligible. The heat loss from the super heated hot water and steam distribution systems have caused sufficient ground heating to damaged some of the chilled water piping; by causing ovaling, blistering and collapse of the plastic chilled water piping. If the ground heat was sufficient to cause damage to plastic piping systems then it stands to reason that the losses are more than negligible. — A

2. Section 6, paragraph 6.2.1
The Central Plant at building 730 has three CHILLERS, two 300 tons and one 800 tons. Chiller Optimization should utilize all three chillers. For low load conditions of 0 to 300 tons, one 300 tons chiller. Medium load of 300 to 600 tons, two 300 tons chillers. High load of 600 to 800 tons, one 800 tons chiller. Peak load of 800 tons and above, one 800 tons and one 300 tons chillers. This strategy will have the chillers operating at 70 to 80 percent of there peak capacity (the most economical portion of there efficiency curve) the majority of there operating time. — A

3. Section 8, paragraph 8.1.2
The difference in cost of a central plant and replacing the existing equipment is what should be compared. — X

VOLUME II

4. C-3 (Reference Review Comment number 11 dated 8 July 1991.)

Building 5900 chiller 4 should be listed as a 450 ton chiller. — A

VOLUME III

5. J.1.8 The drawing indicates that there may be adequate space in the existing mechanical room for the heating and cooling equipment, if one chiller is used, thus eliminated the need for the addition to the building. — X

L 836 Army-Fort Sill, Okla.

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(DEH) 1 Aug 87

SILL REVIEW COMMENTS	DATE: 6 November 1991	ACTION
DIRECTORATE OF PUBLIC WORKS	DISCIPLINE	A CONCUR
	CIVIL	D DO NOT CONCUR
ENERGY SURVEY OF ARMY BOILER & CHILLER PLANTS	ARCHITECTURAL	E EXCEPTION
	XX MECHANICAL	X DELETE
LOCATION: FORT SILL, OKLAHOMA; PROJECT NUMBER: DACA56-90-C-0087	ELECTRICAL	(EXPLAIN D, E, & X)
	FIRE PROTECTION	ACTION BY
CMT. NO. / DWG. NO. / REVIEWER: JERRY SCHMIDT	PHONE NUMBER: (405)351-4250	-----

CMT. NO.	DWG. NO.		ACTION BY
6.	J.1.4 & J.1.5	If the scope is reduced from two chillers to one chiller and eliminating the addition to the building the project bare cost could be reduces approximately $200,000. (Building addition $120,000 Chiller $80,000)	A
7.	L.1.4	If the chiller sizing is based on the combined load of the connected buildings (Reference Volume II page B-5) 305.7 Tons and a diversity factor of 0.85 used the chiller size should be 260 Tons. This down sizing of the chiller from 342 Tons to 260 Tons should increase the energy savings and lower the cost of the chiller without altering the comfort level in the buildings.	X